TECHNOLOGY TRANSFER TO DEVELOPING COUNTRIES WITH SPECIAL REFERENCE TO THE ECONOMY OF THE REPUBLIC OF CHINA

By

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The purpose of this study is to examine the nature of forces affecting, and the mechanisms mediating, the technological transfer process to developing countries. In particular, this is a study of the impact of technological progress and capital formation on economic development with special reference to the manufacturing sector of the Republic of China.

Major emphasis is on inquiry into the nature and pattern of technological progress in the manufacturing sector as a whole and in each sub-industry of the manufacturing sector, as well as its relationship with major economic indicators of the economy such as output productivity and capital formation.

After broadly reviewing the relevant literature in two major areas, economic and non-economic aspects of technological transfer, a theoretical framework has been established for reviewing and evaluating the nature

and mechanisms of technological transfer from developed countries to developing countries. An interface model of international technology transfer has also been built up to give the reader a clear picture of the transfer process.

Actual data have been collected mainly from the *Census of Manufacturing* and *The Report on Industrial and Commercial Surveys* for the years from 1966 to 1975. The data have been used for fitting CES production function models to estimate the rates of technological progress and elasticity of substitution between factor inputs.

The research findings are 1) During the ten-year period 1966-1975, there was no structure break in terms of technological progress. A quasi structure break was found around 1971-72. The momentum of technological progress was dragged down by the world recession in 1974. It was also found that labor-intensive industries were more vulnerable in competition with capital-intensive industries under conditions of world recession. 2) Technological progress in the manufacturing industry over the ten-year period was not neutral. The efficiency of labor grew faster than that of capital. Technological progress was biased toward labor-saving and capital-using. 3) Productivity in the manufacturing industry was found to be correlated with output and capital intensity which is a function of capital formation. Foreign investment was found to be correlated with capital formation. Foreign investment, therefore, made contributions toward total production through capital formation.

In short, economic growth is a function of productivity which is technology determined and technological progress is a function of capital formation.

CHAPTER I.
INTRODUCTION

Modern technology is crucial for the economic development of developing countries (DCs). This is particularly true for the stage of economic development in Taiwan, the Republic of China (ROC), that is now in a transitional period from a developing to a developed country. Substantial increases in per capita income, diversification of products, and a tremendous expansion of trade customarily involve the use of new equipment, new tools of production, new skills, new designs, new processes, new modes of organizational, managerial, administrative and technical know-how.

The innovations required for the above changes come from two sources: Endogenously, they come from the economy itself through the small scale efforts of imaginative individuals and the large scale efforts of private and public organizations, especially through the strenuously concerted efforts of the government in laying down the national campaign for technological development; and exogenously, from beyond the economy's own borders through technological transfer from advanced countries (ACs).

Technology can be acquired from external sources in a number of ways. Unfortunately, technology can not be transferred in ordinary markets because technology is not an ordinary commodity. The processes of technological transfer, therefore, are indeed very complex phenomena.

It is the purpose of this study to examine the nature and forces affecting, and the mechanisms mediating the technological transfer

process to DCs in terms of impact of technological progress and capital formation on the economic development with special reference to the manufacturing sector of ROC.

In the course of inquiry the following probelms will be dealt with:

1. What is the nature and pattern of technological progress in the manufacturing sector as a whole, and in each sub-industry?

2. How do the nature and pattern of technological progress correlate with aggregate indicators such as output, labor productivity, employment, and capital formation?

3. Is technological progress neutral or biased toward factor intensity?

4. What is the impact of foreign capital on the overall economic growth?

5. Is there any relationship, in an inter-industry correlation analysis, between manufacturing output, output per man, employment, elasticity of factor substitution, technological progress, capital intensity, and capital formation?

Taiwan has been chosen for this study for several reasons:

First, it exemplifies rapid economic growth.

Second, the unique nature of its economy;

Third, its essential need for technological transfers from advanced countries in order to maintain its sustained growth toward being a developed country; and

Fourth, the conclusions drawn from a theoretical and empirical investigation can be applied to other developing countries as a reference in coping with their technological transfer problems.

Economic growth is usually defined and measured in terms of the increase of a nation's gross national product, the rising productivity, the economic stability, the strength of the social development, the balance of payment position in the international market as exemplified in the nation's foreign trade, the decline of the unemployment rate, and the narrowing of the gap between the rich and the poor in the country. Measured against all the standards, Taiwan's economy has indeed made great strides in the past twenty years. [1]

First, the economic development accomplished in Taiwan by the Republic of China during the last two decades may be considered as an excellent model for those underdeveloped countries who are interested in economic growth and development. [2] Taiwan's rapid economic growth may be validated by several significant economic indicators. The major one is gross national product.

During the period 1952 to 1972, Taiwan's GNP increased at an annual average rate of 15.2% at current prices or about 8.8% expressed in 1966 prices. [3]

Second, Taiwan is a small island of approximately 13,808 square miles with a population of 16 million. With its small size, low per capital income (U. S. $52 in 1952 to U. S. $700 in 1976), Taiwan has a limited domestic market and its natural resource base is poor. Under such conditions, Taiwan's accelerated growth in per capita income is virtually impossible. Its total foreign trade has increased from U. S. $300 million in 1952 to U. S. $15 billion in 1976.

Besides, Taiwan's military burden is extraordinarily heavy. According to the estimation of N. H. Jacob, [4] the military expenditures

averaged from 9 to 11% of the GNP during 1951 - 1965. These expenditures constituted about 85% of the total outlays of the Chinese Central Government, and about 50% of the combined outlays of the government at all levels.

Under such constraints, Taiwan's economic boom may be termed as a miracle in the economic history of the world. There must be some reason behind the miracle. One of them may be the technological transfers from advanced countries. Furthermore, the announced policy by the Chinese Government for the next Six-Year Economic Development Plan is toward the development of heavy industry which will be desperately in need of modern technology transferred from ACs.

This research is an exploratory inquiry into the overall process of technological transfer and the possible linkages between capital accumulation and economic development. As mentioned, international technology transfer (ITT) is a very complex phenomenon. It involves sociocultural, behavioral and informational variables. The major emphasis in this study will be on economic analysis of technological transfer.

Since World War II, the technology gap between ACs and DCs has been widened because of the inadequate mechanisms of ITT, distortions of capital formation and market imperfections. This grave situation in ITT has been brought to the attention of world leaders, and the need for technological transfer from ACs to DCs to accelerate the economic development of the less developed countries has been recognized and stressed in various United Nations bodies. General Assembly resolution 1713 (XVI) of December 19, 1961 emphasized certain aspects of technology transfer, and the overall question of such transfer to DCs was dealt with comprehensively in resolution 2091 (XX) of December 20, 1965. The recent development

on the importance of technology transfer has also been voiced by the world leaders in the North-South Conference held in Europe in 1976.

Since economic development is a world-wide goal and economic development is a function of technological progress which, in turn, is a function of capital formation, especially foreign capital mainly by way of foreign direct investment, nowadays the tensions between ACs and DCs (or so-called third world) are essentially caused by the unbalanced economic development or the widening gap of technology. The only way to alleviate this situation is, therefore, to expedite the process of technological transfer from ACs to DCs and to establish a theoretical framework for evaluating the transfer processes.

Unfortunately, the current literature reveals that systematic and empirical investigation of technological transfer between ACs and DCs is lacking. The existing literature is abundant in certain areas, such as foreign direct investments and multinational corporations; but short of comprehensive investigation of relevant facets on the commercialization of technology. Essentially, its dynamic process which involves the characteristics of the technology itself, the mechanisms of transfer, the environments in which the technology is developed and transferred both in ACs and DCs has not yet received the attention it deserves from the international management scholars and economists.

Georges P. Leroy[5:1-2] indicates "The bulk of the research into the phenomena of the multinational enterprise has attempted to identify the main characteristics of these firms in terms of industrial structure, turnover, value of assets, profitability, research and developmental outlays, and to study the impact of multinational firms or nation states . . . . very few studies have been directed toward explaining

how multinational enterprises innovate and diffuse their innovations worldwide."

Some literature advocates that technological transfer from ACs has played an important role for the economic development of the DCs, such as 'Economic Analysis Report on Foreign Direct Investment' published by the Investment Commission, Ministry of Economic Affairs, Republic of China, July 1965. Ghassem Salehkhou,[6] on the other hand, condemns the exploitation by the MNCs from the ACs because overpricing and the restrictional clauses in the technological transfer contracts has limited the growth of Iranian technology recipient firms.

Concerning the controversial issue on whether DCs are benefited or exploited by ACs through foreign direct investment, it should be tested with empirical data to see whether foreign capital has contributed to the technological advance, because productivity is technology determined and technology is a function of capital formation. Some theorists argue that the relationship between technological progress and foreign capital formation is very slim because there is a poor link due to the poor absorptive base (or science base) in the DCs. The experience exemplified by the 'learning-by-doing' hypothesis is very little. In order to throw more light on the above issues, actual data are collected to test hypotheses and to discover significant variables and relationships between technological progress, capital formation and economic development.

At first, by comparative analysis and reviewing the relevant literature, a theoretical framework is established as a guideline for reviewing and evaluating the nature and mechanisms of technological transfer from ACs to DCs. Since international technology transfer

involves sociocultural, behavioral, and informational aspects of knowledge, for the convenience of analysis, the discussion is divided into economic aspects and non-economic aspects of technological transfer. Secondly, an interface model of international technology transfer is designed which consists of two large components: one is a management information systems of international technology transfer, another is an invention-innovation-diffusion process. From this interface model, the reader will have a clear picture of the whole process of technological transfer from ACs to DCs.

CHAPTER II.
FUNDAMENTAL CONCEPT OF ITT

1. Introduction

International Technological Transfer (ITT) is defined as internationally borrowing or diffusion of emobdied or disembodied technology across national borders. Embodied technology transfer is usually through the importation of capital goods. Disembodied technology transfer is through the inflow of managerial, administrative, and technical know-how. There are many ways through which both types of technology, embodied and disembodied, can be brought in. Nowadays, however, the major mechanism of ITT, since World War II, has been foreign direct investment (FDI) which carries not only money capital but human capital as well. With money capital, FDI imports capital goods embodied with modern technology which is vitally important for improving labor productivity. With human capital, FDI brings in modern managerial, administrative, and technical know-how which is no less than the importance of capital goods. International Technology Transfer, therefore, involves capital accumulation, which, in turn, is a function of saving and investment, and technological progress (embodied or disembodied). The whole process of ITT, therefore, relates and interacts with economic, sociocultural, behavioral, and informational aspects of phenomena which will be discussed in the following chapters, but the major emphasis will be on economic analysis. In order to place this study in a proper context, it will be necessary to briefly mention the related topics.

2. Technology Evolution

Modern technology is crucial for the economic development of both DCs and ACs. Historically, though it was not neglected by the entrepreneurs and economists, technology has only been recognized as a prime propellant of industrialization and has been intensively scrutinized as a recent phenomenon. As Rosenberg [7:13] states, "Technological change has occupied a curious sort of underworld in economics for a long time. In the work of the classical economists - Mathus, Richardo, the Mills - it was not totally ignored. It played, however, the role of a kind of afterthought which modified somewhat the dimensions of an analysis which was undertaken without it, and in which other variables - population growth, capital formation, diminishing returns in agriculture were regarded as more important." He continues to elaborate the evaluation of technological change by saying that though Marx focused attention forcefully upon technological change as the prime mover in capitalist development in the middle of the nineteenth century, his work had little immediate impact upon the traditional management and economics. At the turn of the nineteenth century, optimal resource allocation was emphasized, but the analysis was focused along a line of static framework in which technological progress was excluded.

Joseph Schumpeter,[8] in the second decade of the twentieth century, advocated that technological progress played a vital part in the capitalist system. Unfortunately, in his framework, technological progress was assumed to be exogenously determined. The effect of technological progress on total output was separated from that of capital accumulation. He took inventive activity as an exogenous force, which had important impact on economic development, but no causal relationship. He, therefore, says

relatively little about capital accumulation influencing inventive activity which seemed to live a life of its own. This approach has been criticized as unrealistic because evidence, in the past three decades, had indicated that technological progress is a major factor of rapid economic development which can be examined directly in terms of economic analysis. Even though the tools of analysis are still in a primitive stage, the economic reasoning does provide a meaningful insight into technological progress. After a general sketch of technological progress of historical evolution, we are going to ask, "What is 'technology,' 'technological progress,' and 'technology transfer.'"

3. Technology, Technology Change, and Technology Transfer

"Technology may be defined as the means or capacity to perform a particular activity" according to Gruber and Marquis.[9:255-6] "The transfer of technology must then mean the utilization of an existing technique in an instance where it has not previously been used. This transfer may be merely the acceptance by a user of a practice common elsewhere, or it may be a different application of a given technique designed originally for another use." Mansfield [10:10-11] defined technology as ". . . society's pool of knowledge regarding the industrial arts. It consists of knowledge used by industry regarding the principles of physical and social phenomena . . . , knowledge regarding the application of these principles to production . . . , and regarding the day-to-day operations of production. Technological change is the advance of technology, such advance often taking the form of new methods of producing existing products, new designs which enable the production of products with important new characteristics, and new techniques of organization, marketing and management."

Technology consists of scientific, technical and sociocultural knowledge. It refers not only to tools, but includes tool-using behavior, a set of complex elements. Solo and Rogers[11:3-4] stated, "Technology will be understood as the organized capability of a social group to perform some purposeful activity. . . . it can conceivably be reproduced, duplicated, systematically perpetuated. For any society the whole complex of organized capabilities interrelate and interdepend."

4. Technology Gap

After World War II, beyond all expectations, the technology gap between ACs and DCs widened. Strassman[12:13] said, "Countries with the lowest standards of living developed most slowly and international disparity widened. The setting was auspicious for new diagnoses of low productivity and new cures." This situation has brought the attention of the world leaders. The need for expediting transfer of technology from ACs to DCs to accelerate their economic development has been recognized and stressed in various United Nations bodies.

What is the technology gap? According to Jan Kmenta,[13:39] "The pool of available technical knowledge consists of knowledge actually applied in production plus knowledge that - although potentially applicable - has not been used in practice. The size of this pool can be referred to as the 'level of technology.' This level is considerably higher for developed countries compared with the underdeveloped parts of the world; the difference between these levels constitutes a technology gap." The higher the level of technology the greater the implication of more efficient utilization of resources, and therefore higher output. Raising the level of technology of DCs so as to raise the output has become the pressing problem for the economic development of DCs.

This technology gap is created by inadequate and distorted transfer of technology, distortion of capital formation, market imperfection, inequality of factor endowment and factor proportion, and lack of national effort in fostering absorptive capability so as to have a poor link between capital accumulation and technological progress. The predetermined factor proportions embodied in the modern capital goods is a real one, because modern equipment developed in ACs are generally labor-saving (capital-using). They are not readily and completely transferable for lack of fitness with DCs' factor endowment. It is a common phenomenon that the DCs are heavily endowed with abundant labor and shortage of capital. What they need, therefore, is capital-saving and labor-using equipment.

Foreign direct investment, since World War II, has become the major vehicle in bringing modern technology to DCs through modern equipment importation. It also can not guarantee the success of transfer because of science base difference between ACs and DCs. The so-called advantage to the late comers in technology utilization fails to pay attention to the shortage of science base which causes a weak link between the technology imported and the absorptive capacity. This will make the advantage disappear completely and technology gap further widened. No student can be taught advanced calculus unless he has the knowledge in basic algebra. From an economic point of view, transferring modern technology from ACs would be much cheaper than developing the technology endogenously. There is a limit, however, that DCs must have the basic technological base or scientific base locally for absorptive purposes. With these basic concepts in mind, we will make further investigation into sociocultural, behavioral and informational areas of

technological transfer which, for convenience of investigation, will be organized into two large areas, economic aspects and non-economic aspects of international technological transfer. Though the major focus of investigation in this study will be placed on the economic aspects of international technological transfer, it does not mean that the non-economic aspect of ITT is not important. Due to the space limitations, we shall have to confine our investigation within a manageable proportion.

CHAPTER III.
NON-ECONOMIC ASPECT OF ITT

I. Technology Viewed as a Total Cultural Change

Technology, innovation and diffusion have been conceptualized in a number of ways. Some view technology just as machines or artifacts. A second approach adds to the physical objects, labor, managerial and administrative skills - this approach has been widely adopted by economists. A more sophisticated approach views technology as a socio-cultural phenomenon; but the author views technology and consequently technological change and diffusion as a socio-cultural, behavioral and informational phenomenon that means, technology and technology change and diffusion have been conceptualized as incorporating social, cultural, behavioral, political and economic process as well. In this view, the central values of the culture play a very important role in the formation of technology and in the innovation and diffusion process. Though most economists reject it on the ground that cultural and behavioral variables can normally be taken as constant, we do not believe it is a legitimate reason. The real problem is that an all-embracing approach is difficult to formulate under the present state of the art. Thus, economists do not reject the importance of non-economic variables, only the necessity of concentrating upon them for the convenience of investigation.

The more realistic approach would be the one that takes the necessary elements into consideration; as John Joseph Murphy[14:6] indicates, "A much more meaningful approach is one that falls between reliance upon technology as total cultural change, and reliance upon technology as just

the direct relation between capital and cooperating labor. The economic historian has to recognize that machines operate with more than complementary factors of production; they also require complementary economic units. The success of any technological change, therefore, is contingent upon the ability of other operations to adapt their mode of action to the necessities of the innovation." Technology does not just involve capital and labor, but the whole system from factor suppliers to the final marketing outlets. It indicates that technology and its innovation and diffusion need to cooperate with every subsystem in a harmonious way. Technology and its innovation and diffusion interact with factor inputs, market conditions and the whole social system in which they operate. We may, therefore, conclude that the success of technological transfer and diffusion is a function of the ability to change processes that require system adaptations, and the processes of adaptations involve not only receiving countries (or parties) but also the giving countries (or parties) as well.

Under the whole system concept, a successful technological transfer hinges upon the compatibility of certain subsystems that exist in the transfer process, because these subsystems must be able to adapt to the requirement of the whole. These subsystems include internal machine-labor ratios, organizations, information systems, decision channels, and external environment. This approach to technology takes technology and its change as interdependent and interrelated with its internal organization and external environment. We may interpret it this way, that one component of a process may not be transferred to another process without transferring or developing compatible system components. It does not mean that single components of a production process or a system

cannot be replaced at any point of time. Of course, any single movement in a system will exert pressures or tensions that call forth advances in other parts of the system; like a marble in a bowl of marbles, it is unlikely that one marble can be moved without moving the others.

This system concept can be used to explain why technology development and diffusion have occurred more successfully and faster in one country (or region) than in another; because technology development and diffusion is a process, the ability to innovate and diffuse technology is determined by a system change. These system changes to be effectuated will require both economic and value modifications. The extent to which the modification can be made depends upon the compatibility of the subsystems. This is the reason why technology development and diffusion need not only scientists and engineers but also enterpreneurs, social psychologists, and government officials to make the whole system function, and these modifications will have to occur before, during, and after the diffusion. Any given technological change starts a sequence of actions that create areas wherein adjustments have to be made in order to maintain the system functioning as a whole. So technology development and diffusion is a continuous process and evolution.

2. Conceptual Models

As we have already indicated that technology and its transfer or diffusion are best viewed as a process, and the processes are, in turn, best exemplified by models which will tell us their interdependence and interrelationships, development of the models will provide a framework for understanding the process of transfer and specifying definitions

and concepts underlying the transfer. Three models were developed by the M.I.T. Conference on Human Factors in the Transfer of Technology (9, William H. Gruber and Donald G. Marquis, 1969). The conference was attended by a modest number of scientists, engineers, historians, political scientists, and sociologists; and the conference was called on the assumption that human factors would be a useful focus of attention and perhaps the critical variable in the process of transfer.

The first model is a science, technology and the utilization of products model, (Fig. 1). This model provides a topological view of the relationship between science, technology, and the ultimate uses of science and technology. By using the model, we can trace the loci of transfer that take place and the possible sources of idea generation. This model, through time, presents the flow of science, technology, and the utilization of technological outputs. Transfer can occur between the three flows or within a channel. This is a system view of technology transfer. It is done by system analysis through the examination of the major channels of activity.

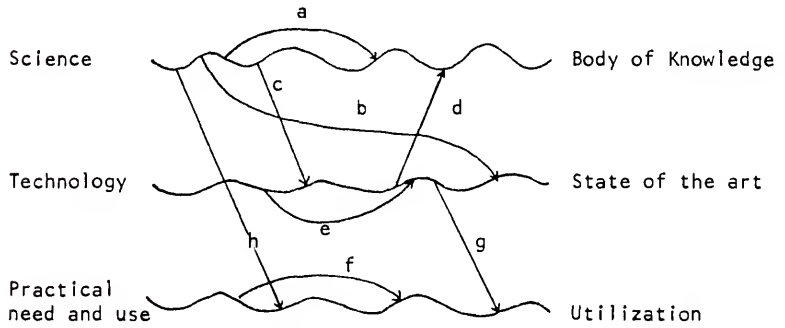

Figure 1. Science, Technology, and Utilization of Products Model

a=Science to Science
b=Science to technology (Slow)
c=Science to technology (Fast gap filling)
d=Technology to science (e.g., instruments)
e=Technology to technology
f=Use to use (diffusion)
g=Technology to use
h=Science to use

The second model is a probability of transfer model (Fig. 2). Given any bit of technical information, this model provides a sequential series of probabilities that might be considered in order to determine whether the given information would be transferred into a new use that would itself result in eventual diffusion.

This model examines the sequence of events within the organization structure of a given potential recipient or user of existing technology. It has two critical links with the external world, one at the point of entry and one at the point of marketing the output of the inventive effort.

P (transfer) = P (Idea)→ P (Research)→ P (Development)→ P (Production)→ P (Innovation)→ P (Diffusion)

Figure 2. Model II: Probability of Transfer Model

The third model is a magnitude of transfer model (Fig. 3). It focuses on the structure of the transfer process. This model examines the magnitude of transfer as a function of a set of factors. The independent variables in the model will often be related to one another, and a given problem would have to be solved simultaneously rather than sequentially.

Magnitude of Transfer = f { Source, Nature of item to be transferred; Structure of channels for transfer; Potential recipients (customers) of item to be transferred }

Figure 3. Model III: Magnitude of Transfer Model

A solution to Model III will often give insight into Model II, e.g., if the channels for transfer in Model III were difficult, this would result in a low probability that an idea would result in research, development, etc. as seen in Model II. If the idea were produced, there would be a low probability that it would succeed the critical test of diffusion. The concept of magnitude of transfer is critical because technological transfer that is not successfully diffused (marketed) provides an example of what usually is a costly error.

These are the preliminary models developed at the conference after recognizing the complexity of the process of technology transfer. These models served a purpose by bringing the related variables in the process of technology transfer into focus. The models that evolved are clearly related to one another despite the fact that each one has its own focus. Gruber and Marquis admitted that in time a more inclusive model that integrates the substance of these three models should be developed.

3. An Interface Model of ITT: (Fig. 4)

(1). MIS of Technology Transfer

As we already mentioned, technology transfer is best viewed as a process wherein the successful transfer is simply a function of information processing and quality of decision-making. Information processing is one aspect in the transfer process. It creates the necessary articulation and communication between the body of technology - in its cognitive state and the population of potential users as well as between the sender and the receiver of technology. Another aspect in the transfer process is the human factors which determine the quality of the

decision-making in the process; in another word, human factors, if properly tempered, can help smooth the transfer, or otherwise it will become a roadblock, increasing resistance to change.

The interface model of ITT consists of two large components: one is An Invention-Innovation-Diffusion process. Another is a Management Information System of Technology Transfer which is, in turn, composed of three subsystems, namely, an information gathering subsystem, an information processing (or organizing) subsystem, and a decision-making subsystem. The information gathering subsystem interacts with the invention-innovation-diffusion process systems and the environment. It gathers information from internal and external sources and performs the function of acquisition, processing, and dissemination of internal and external data.

The Data Processing subsystem (or organizing) subsystem evaluates the supplied event data, converts the data into consumable information; while the decision-making subsystem formulates a problem, identifies alternative solutions, compares the alternatives, chooses and implements a course of action. This MIS of technology transfer can be installed in any public or private organizations for systematic and effective technology transfer. But here we use a different name; In private organizations such as MNC and civilian organizations, we use the name of 'MIS' to show that the MIS can not only handle technology transfer problems but also other decision-making problems because technology transfer is not an isolated phenomenon in any organization. It interacts with almost all decision areas, internal and external to the organization. In public organizations, such as government, the United Nations, and regional organizations, we use the name of 'Information

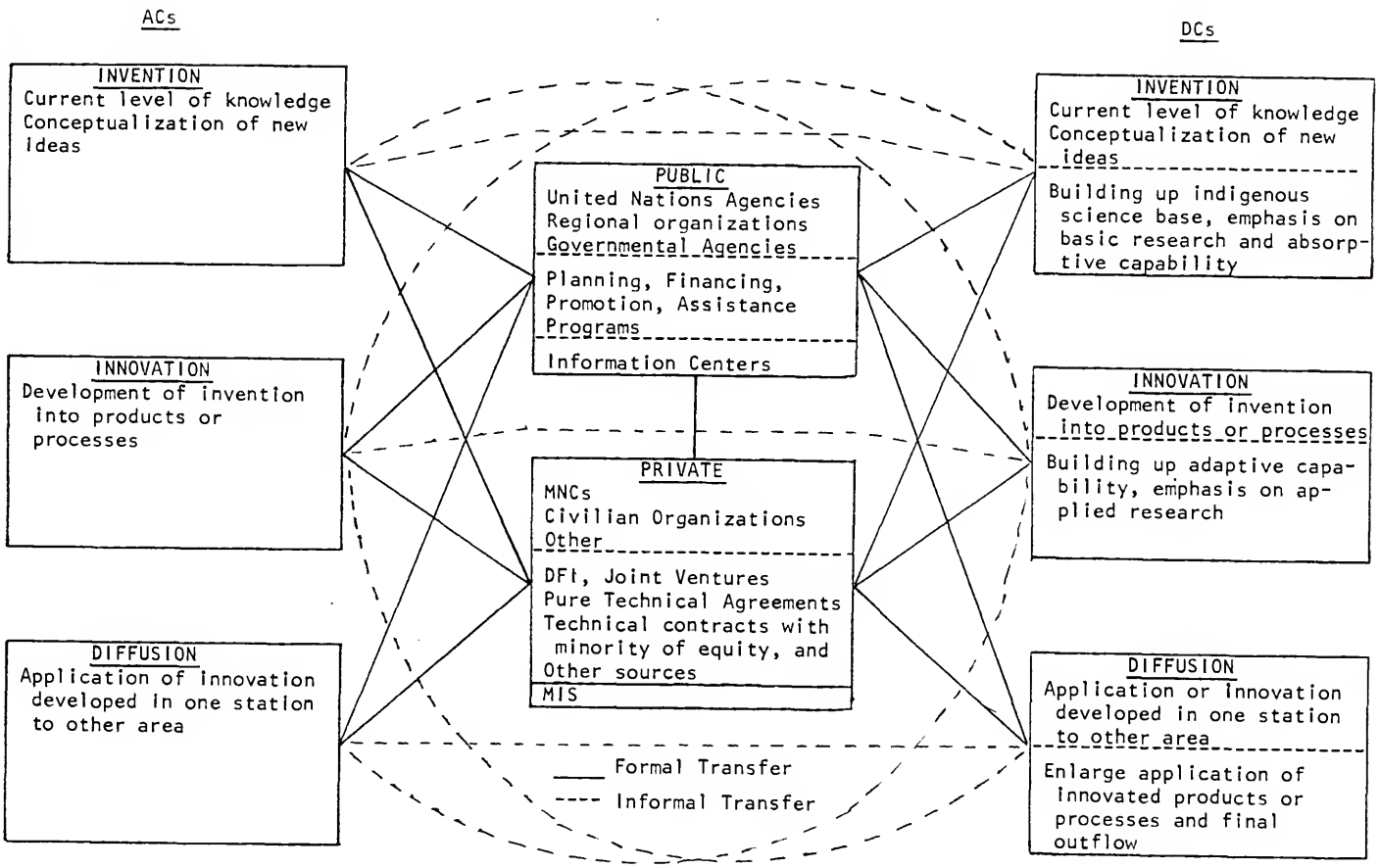

Figure 4: An Interface Model of International Technology Transfer

Center' to show the nature of information concerning technology transfer as slightly different, with the emphasis on planning, financing, promotion, and assistance programs to help the private and public organizations to obtain the necessary technology or to help the private and public organizations that have technology to offer it either for profit or international mutual cooperation. Actually, MIS and information Centers play about the same role in promoting technology transfer.[15,16]

(2). Mechanisms and Information Sources of ITT

Technology can be acquired from external sources in a number of ways. According to a study by the UNCTAD Secretariat, United Nations,[17] the external sources have been itemized as (a) The flow of books, journals, and other published information; (b) The movement of persons from country to country; (c) Education and training; (d) Exchange of information and personnel through technical co-operation programs; (e) Employment of foreign experts and consultancy arrangements; (f) Import of machinery and equipment and related literature; (g) License agreements for production processes, use of trade marks and patents, etc.; (h) Direct foreign investment. DCs in principle can, and in practice do, use almost all of these ways, either singly or in combination, to acquire the various elements of technology for setting up industrial investment projects or improving their existing production operations. The choice of one or of a combination of several ways of acquiring technology is influenced by a variety of factors, such as the outlook and motivation of local enterprises, the nature of the technology, the level of domestic technological and industrial capabilities.

The above static presentation of information sources can not be viewed as a purchasing list with which the technology seekers can

freely buy the technology they want in ordinary markets. Strassman[12:57-60] notes that "Technological information is not an ordinary commodity, and ordinary markets will not transfer it effectively from developed to poor countries. The uncertain value of information not yet owned, the difficulty of owning information exclusively, and its inexhaustibility in use, have led to a complex and still imperfect network for its international diffusion to manufacturers. In part this network consists of schools, libraries, technical periodicals, and trade journals. In part it consists of inquiries and responders who have been compared to a system of relay stations." What the relay stations mean by Strassman is generally equivalent to our information gathering systems, but not systematically organized as we proposed by way of the latest development in management information systems. He points out that a general feature of international technical transfer is that the relay stations are not closely coordinated. A top-level scientific agency monitoring performance as a whole may be needed. During 1965 the United Nations Advisory Committee on the Application of Science and Technology to Development (UNSCAT) considered setting up groups that might carry out this monitoring and stimulating activity in concerted attacks on selected problems. But in the manufacturing area, as he explained, the committee had not yet gone beyond general support for techniques that should be relatively small scale and labor intensive, using indigenous raw materials and versatile equipment. A narrower project was to follow proposed pilot projects in technology transfer centers and to make case studies of present transfers in selected industries.

Strassman believes that the foreign subsidiary of a multinational corporation would be a good example of a thoroughly organized channel of transfer, but he condemns the idea that communication was typically maximized for detailed bureaucratic control, and not for the encouragement of imaginative adaptation. We believe that if the MNC concerned have adopted integrated MIS, this kind of malfunction of technology transfer will be reduced to a minimum. By contrast, he pointed out, some European machinery builders are staffed to provide full services in consulting engineering, an arrangement that increases flexibility in machinery design, but requires more trust by the customer and his bank so as to increase their competitive advantage. Strenuous efforts have been exerted in smoothing the transfer channels by various organizations, such as the governments, private organizations, and United Nations. Our position is that thoroughly understanding the concept of the interface model of international technology transfer and installations of information centers in public organizations and MIS in private organizations according to the concept of the interface model would be the solution of existing malfunctioning of technology transfer from ACs to DCs. Concerning types of technology transfer, they will be discussed in Chapter IV.

(3). Invention-Innovation-Diffusion Process

Invention is defined as the conceptualization of a new idea which has yet no immediate economic significance, since they can be fructified only by entrepreneurs, who are able and ready to find new combinations of factors. Therefore, in Schumpeterian theory[18] inventions play a

minor role. Innovation is defined as the development of an invention into a product that is utilized. Innovations in Schumpeter's sense are applications of inventions by entrepreneurs to increase economic productivity. Innovations are the cornerstone of Schumpeter's theory, since they not only explain the business cycle, are the cause of positive profits, and of a positive rate of interest, but also define the role of entrepreneur. Salin [19] continued to define the basic nature of invention and innovation by saying that innovations, in contrast to inventions, appear discontinuously. They tend to be introduced near equilibrium, where the risks are at a minimum. There is a very slight connection, therefore, between inventions and innovations, because inventions do not stimulate innovations. In Salin's term that the process of innovation can be generated by five different classes of events: by the introduction of a new product, by a new method of production, by the opening up of a new market, by the conquest of a new source of supply of raw materials, and by a change in the organizational structure of any industry. While all these events involve discontinuous change in the combination of factors of production. The motives of the innovating entrepreneurs differ greatly, and in addition to desiring for profit, are largely of a sociological and psychological nature.

Diffusion is defined as application of innovation developed in one station to other stations, one area to another area. The transfer of technology is simply to move an existing technology to another place or utilization of an existing technology in an instance where it has not previously been used. Diffusion is often accompanied with necessary adaptation of the existing technology to environment to which the technology is going to be applied. Here we adopt a little broader meaning,

that means transfer may be merely the acceptance by a user of a practice common elsewhere, or it may be a different application of a given technology designed originally for another use.

The mere acceptance by a user of a common technology is called 'adoption' and the spread of such adoptions is the 'diffusion of technology.' The application of technology in a new way is probably termed as 'innovation.' In this study, the term 'transfer of technology' indicates adoption, diffusion and innovation. If technical elements are brought together in a new way and a new technology results, this would be called an invention until it is used to satisfy a demand, at which point an 'innovation' occurs. Research on the transfer of technology thus focuses on innovation and diffusion of technology which denotes a method of satisfying a particular purpose.[9]

The process of technical advance has been delineated by Gruber and Marquis into four stages based on the invention-innovation-diffusion typology (Fig. 5). Technical advance is defined as an increase in the level of technical knowledge and/or an increase in the economic uses of technical knowledge.

4. Human Factors in ITT

Technology transfer is not moved by itself, but by men. Human factors, therefore, would no doubt constitute a major part of the determinants of a successful transfer of technology, e.g., the factors of demand-feasibility recognition and ability-willingness to combine to determine the utilization. For a more complete understanding of the human factors, a brief review of the following determinants would be helpful:

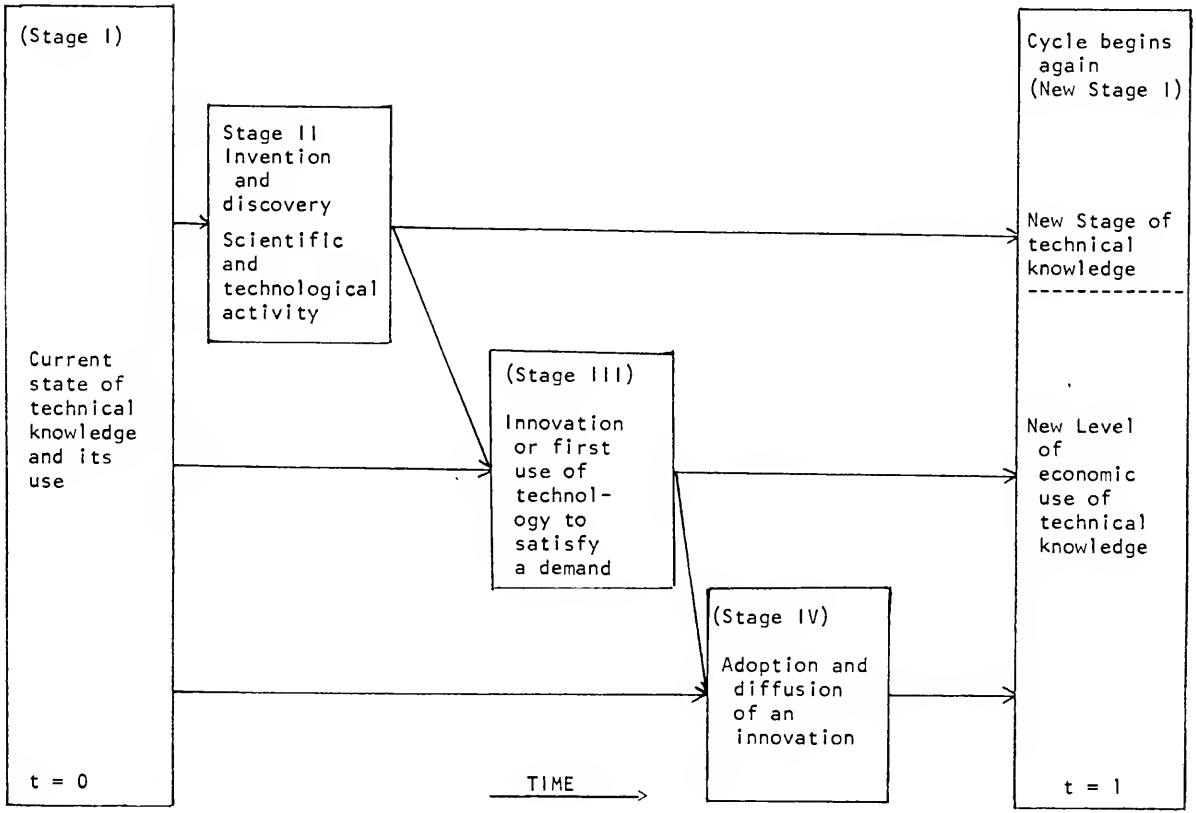
(Stage I)
Current state of technical knowledge and its use
t = 0
Stage II Invention and discovery
Scientific and technological activity
(Stage III)
Innovation or first use of technol-ogy to satisfy a demand
(Stage IV)
Adoption and diffusion of an innovation
TIME
Cycle begins again (New Stage I)
New Stage of technical knowledge
New Level of economic use of technical knowledge
t = 1

Figure 5: A Four-Stage Process of Technical Advance

Cultural Value: Ralph Linton [20:74] states, "If we know what a society's culture is, including its particular system of values and attitudes, we can predict with a fairly high degree of probability whether the bulk of its members will welcome or resist a particular innovation." A norm is defined as the most frequently accruing pattern of overt behavior for the members of a particular social system. Norms influence the diffusion of new ideas and also may be a barrier to change. Everett M. Rogers [21] indicates that there are two ideal types of social norms (traditional and modern). A social system with modern norms is more technologically developed, cosmopolite, literate, rational, and empathetic than that with traditional norms.

Personality Traits: Individuals with need for achievement and motivation for power are generally associated with the successful formation of new technical enterprises by entrepreneurs.

Motivation: is influenced by profitability, competition pressure, reward structure, visibility of results and government regulation.

Training and experience: Recent empirical results indicate that a number of years is required before a technically trained person is likely to contribute to significant technical events. Shapiro found that regions where the newer, more advanced technology was concentrated had technical personnel with a higher average level of education than that of personnel in regions with older, less dynamic technology.

Organizational effects: These depend upon the degree of rigidity established within the bureaucratic structure that will usually be resistant to change.

Mission Orientation: This results in emphasis upon the recognition of organizational objective, rather than functional objective, because demand creates the awareness of a need for new technology.

5. Learning-by-Doing Hypothesis

The acquisition of knowledge is what is usually termed 'learning' and this concept has gained increasing importance in the explanation of productivity gains which make output growth possible. According to Engel, Kollat and Blackwell[22:114] and Hall[23:3-6] "Learning may be defined as changes in response tendencies due to the effects of experience." Rogers[21:77] noted that "Learning is defined by psychologists as the relatively enduring change in the response to stimulus." The heart of most learning theories is the stimulus-response relationship. A stimulus is interpreted and causes a response in the individual. Continued reinforcement of this response by later stimuli results in a more or less permanent change in the individual's behavior; this is learning. This is a S-R connection view of learning as being strengthened by practice and positive consequences and this is also a reinforcement approach to learning. But a cognitive approach, on the other hand, takes learning as a process of cognitive reorganization. Perception is seen as a process of relating incoming data to existing cognitive structure. Learning and other behavior may be a consequence of tension and tension reduction, but capacity fulfillment is at least equally important in the determination of behavior.[24] Both approaches to learning, reinforcement approach or cognitive approach, are important in the explanation of acquisition of knowledge. Arrow[25:156-7] notes that, "Of course, psychologists are no more in agreement than economists, and there are sharp differences of opinion about the process of learning. But one empirical generalization is so clear that all schools of thought must accept it, although they interpret it in different fashions: Learning is the

product of experience. Learning can only take place through the attempt to solve a problem and therefore only takes place during activity. Even the Gestalt and other field theorists, who stress the role of insight in the solution of problems (Kohler's famous apes), have to assign a significant role to previous experiences in modifying the individual's perception." The process of learning, therefore, is exactly the same phenomenon of improvement in performance over time.

From the above phenomena that learning is the product of experience, we may say that knowledge is growing in time, and knowledge is also the cornerstone of technological advance which is the prime propellant of economic growth; because with better knowledge, the productive labor can increase their productivity so as to increase total output. Arrow [25:56-7] states that, "It is by now incontrovertible that increases in per capita income cannot be explained simply by increase in the capital-labor ratio. Though doubtless no economist would ever have denied the role of technological change in economic growth, its overwhelming importance relative to capital formation has perhaps only been fully realized with the important empirical studies of Abramovitz (May, 1956, pp. 5-23) and Solow (1957, pp. 312-320). These results do not directly contradict the neo-classical view of the production function as an expression of technological knowledge. All that has to be added is the obvious fact that knowledge is growing in time."

The basic assumption is that technology is embodied in capital goods and experience can be gained in the use of modern equipment. A further assumption is that the newer a machine is, the more advanced the technology; and hence the performance <u>embodied</u> in it, and the more one learns from using it. This learning is then measured in terms of

productivity gains. As we know, productivity is closely related to output. The higher the productivity the higher the total output. The hypothesis of learning-by-doing explains the output increase without increasing the production cost. The older a machine is, the less new knowledge it imparts to the user. The effectiveness of learning, therefore, depends on the age distribution of the equipment and the accompanying adaptive investment to the local conditions. This is the embodied version of the phenomena where learning enters the conditions of production. Arrow indicates that, "I follow here the model of Solow[26] and Johanson [27], in which technical change is completely embodied in new capital goods." But at the same time, he also mentions that there is a so-called 'Horndal Effect.' The Horndal Iron works in Sweden had no new investment (and therefore presumably no significant change in its methods of production) for a period of 15 years, yet productivity (output per manhour) rose on the average close to 2% per annum. He finds this steadily increasing performance which can only be imputed to learning from experience (Lundberg,[28:129-33]). Jan Kmenta [13] also indicates that technological improvement can be imputed to learning from experience with production. In other cases, technological progress without investment may be due to new methods of production, or to new modes of managerial and administrative operation. The latter one is a disembodied technological advance in nature.

These are equivalent to the dichotomy of embodiment and disembodiment of technology progress which will be discussed in Chapter V. Here are listed a few methods in choosing the economic variable which represents 'experience,' a neutral type of technological advance in this sense.

The role of experience in productivity gains has been to show that the number of labor-hours required in production is a decreasing function of the total number of items of the same type previously produced. Verdoorn [29] has applied this principle of the 'learning curve' to national outputs, under the assumption that output is increasing exponentially, current output is proportional to cumulative output, and it is the former variable that he uses to explain labor productivity.

This type of hypothesis assumes that technological progress due to experience is a neutral type of technological advance and the possibility of factor substitution is temporarily ignored. The simplified model, Arrow proposed, is to choose the economic variable which represents 'experience.' The above examples suggest that cumulative output may be used as an index of experience. Arrow prefers to use cumulative gross investment (cumulative production of capital goods) as an index of experience, because each new machine produced or put into use is capable of changing the environment in which production takes place, so that learning is taking place with continually new stimuli. This is a continued learning in a sense, and hence a steady rate of growth in productivity.

In short, the improvement in the quality of the labor force over time as a source of increased productivity is important. The assumption that learning takes place only as a by-product of ordinary production is not sufficient because society has created institutions, education, research and development, which have made learning occur more rapidly. Both types of technological progress, neutral and non-neutral, are vitally important for the explanation of economic growth. The model so designed should embrace both types of technological advance,

embodied or disembodied, in understanding the relationship between technological change and output growth.

CHAPTER IV.
ECONOMIC ASPECT OF ITT

1. Economic Development, Capital Formation and Technology Progress

Technology transfer is the vehicle of economic development and technology in turn is a function of capital formation. These three, technology development, capital formation, and economic development, are interrelated and interdependent. The theoretical links among the three will be scrutinized as a theoretical framework for the empirical measurement in Chapter VII.

Here we have chosen technology progress and capital formation to explain the economic growth, not because the two factors exhaust the list, but because they do provide meaningful insight into growth as a good starting point in economic analysis.

Economic growth is usually manifested in structural change, increasing labor productivity and growth of output. Labor productivity is technology-determined and technology is a function of capital formation. This output growth in turn increases income and creates further capital accumulation and technological progress. It is a chain effect. Does this chain effect automatically push the economy up to a new plateau? Does more capital mean higher economic growth? It is too simplified. Evidence indicates that capital formation is a necessary condition, but not a sufficient condition. Economic development is not limited by capital, but by the capability to absorb modern technology which is the real cause of rapid economic growth. Here technology includes not only tools, modern equipment, but managerial and

administrative know-how. Williams [30:110-2] points out that, "Growth is a big and complex problem . . . . Growth is sometimes treated as a simple function of the investment (or saving) rate . . . . To get more growth we simply push up the investment rate . . . . One possible conclusion to be drawn from these relations between growth and investment rate is that the productivity of investment has played a much more important part than investment rate in determining differences in growth rates."

2. Capital Formation

Historically, capital formation has occupied an important role in explaining growth, both in post-Keynesian and neo-classical growth models. Development theorists and growth theorists alike have usually emphasized the role of the saving ratios and capital formation. Development theorists pay less attention to technological progress in the development process of DCs. [31] Schumpeter [32:68] indicates, "That rudiment of a pure economic theory of development which is implied in the traditional doctrine of the formation of capital always refers merely to the saving and investment or the small yearly increase attributable to it. In this it asserts nothing false, but it entirely overlooks much more essential things. The slow and continuous increase in time of the national supply of productive means and savings is obviously an important factor in explaining the course of economic history through the centuries, but it is completely overshadowed by the fact that development consists primarily of employing existing resources in a different way, in doing new things with them, irrespective of whether those resources increase or not."

Capital formation comes from domestic saving or foreign direct investment. Saving, as part of national income not consumed but which goes into investment or net additions to capital stock for productive purposes, has made contributions toward output growth. It, however, contributes less than technological progress according to Solow's study[33] on U.S. non-farm sector. The cumulative upward shift in the production function between 1909 and 1929 was about 80%. Only one-eighth of this is attributable to increased capital per manhour, and seven-eights is attributable to technological progress. Of course it is hard to say exactly the percentage which is attributable to capital formation or to technological progress, because there is a wide range of overlap in the investment in capital goods and in technological progress. Besides, technological progress is a function of capital formation. There are other growth theorists who advocate that output growth is more attributable to factor inputs than to technological progress, e.g., Jorgenson and Griliches's [34] empirical result (measured growth of output in U.S. during 1945 - 1965) belongs to this category. The evidence showed by the former group has, however, been widely accepted as more popular.

We mentioned earlier that early development theorists took the output increase caused by technological progress and capital accumulation based on the production function concept and the effect of the two on output was treated separately by estimating a residual which is attributable to technological progress. Actually, separate treatment of technological advance and capital accumulation is misleading because they are interrelated and interdependent. The assumption of the existence of perfect, competitive factor and commodity markets is also unrealistic. There are a number of market distortions. Capital formation is really

the vehicle of technological advance which, in turn, is the carrier of economic growth, but under certain circumstances, the capital formation will be handicapped by the poor link with host countries' absorptive capability, such as the investment for adapting modern technology and agressive national effort for systematic technology transfer.

(1). Foreign Direct Investment

Investment has dual effects on economic growth, i.e., capital is a demand for output, and at the same time it also increases the economy's productive capacity to produce additional output. The Keynesian model of output and income determination takes capital mainly from the demand side. The increasing productive capacity effect is not fully considered. However, capacity effect is vitally important to economic growth. We may also term it a technology effect. Especially, foreign direct investment brings in not only money capital, but technology as well.

John H. Dunning [35:146-50] states, "Basically there are three ways in which such contribution might have been made. First, U. S. firms might have used (or have caused to be used) resources that would otherwise have remained unemployed. Second, they might have brought about (directly or indirectly) an improvement in resource allocation, by redirecting resources from slow-growing to fast-growing industries. Third, by the injection of new technology and more aggressive managerial attitudes, they might have helped raise the efficiency of production in whatever sectors they invest, and/or speeded their rate of growth. The first two of these effects essentially arise from the (money) 'capital' component of U.S. investment and the efficiency with which U. S.

enterprises choose their European outlets; the third arises from the 'knowledge' component - though, in practice, the two effects can not easily be separated."

The knowledge (technology) effect, through what Quinn (1968) and others have called the "technological" multiplier, affects the productivity and growth of particular sectors in the host country, as both new markets are opened and production processes improve. By providing a kind of infrastructure of knowledge, the same knowledge (technology) effect creates spillover effects, and acts as a catalyst for growth which may far outweigh the initial demand-stimulating effects.

Theoretical background of capital influence on growth can be best described as a ratio of capital to output. [36] Domar [37] used the reciprocal of the capital-output ratio to indicate the average productivity of capital (Y/K). If the stock of capital increases, and technology progress is held constant, then $\Delta Y/\Delta K$ indicates the ratio of the increase in output. Domar termed this ratio "potential social average productivity of capital."

The investment effect on output may be generally divided into three areas. The first is termed as "capital widening." The capital must go up as the economy expands so that each new worker will have the same amount of capital as those already in the working force. The second effect is called "capital deepening" as over time the ratio of capital per worker is likely to increase. The third is called "capital quickening" as old equipment is replaced by new that increases productivity. Especially, the second and third effects can have tremendous impacts on productivity to cause economic expansion if bottle necks in skilled labor and absorptive capacity can be overcome. Besides, there

is usually diminishing return on additional capital formation. Technological progress must be used instead to offset the inverse effect so as to maintain a balanced growth along with output.

As we mentioned, foreign direct investment is one of the mechanisms in technology transfer. Since World War II, FDI has made some dramatic changes, such as: (1). The shift of private foreign investment away from portfolio and toward equity investment. (2). The reorientation of the destination of private foreign investment toward flowing from ACs to DCs. (3). The project orientation of private investment. While the portfolio investment was financing infrastructure projects, direct investment was much more diversified. Generally, the evolution of the private foreign investment is from indirect investment toward direct investment. It differentiates itself from other international capital movements. It not only involves capital, but a package of inputs including capital goods and technological know-how. In sum, FDI involves the transfer of both human capital and money capital. Both are vitally important for a nation's economic growth. Technological progress, therefore, is an induced function of investment.

(2). International Trade

International trade is the carrier of international technology transfer. International Technology Transfer, in turn, is the vehicle of economic development. Economic development depends upon capital imports and technology imports. Both can be obtained through international trade. Besides, through exports, DCs obtain foreign exchange for imports of capital good which usually carry modern technology which is vital for a country's industrialization.

Traditional trade theory, based on comparative advantage or factor endowment, can not fully explain the phenomena of FDI. The reasons for this failure lie in the limitations of explicit assumptions of factor immobility and in neglecting or even ignoring the technological progress. Seev Hirsch [38:335-6] states, "A more recent and seemingly productive line of approach focuses on technology, which in the traditional factor proportions models does not receive satisfactory treatment. Technology, i.e., the state of the art, is assumed in the traditional model to be stable and universally available. Producers, regardless of their location, are assumed to be familiar with all technological options available, and they choose that technology which best suits their country's factor endowment. This approach ignores technological change, which is a short-term rather than a long-term phenomenon. It also ignores the costs of developing and adopting different technologies, which may well vary between countries in a systematic fashion." The best way to remedy this limitation, Hirsch suggested, is to incorporate technology into trade models, and to treat it as a capital augmenting factor, not as a free factor readily available universally.

H. G. Johnson [39] and H. B. Lary [40] have suggested that capital should be redefined to include human capital following the above approach. The alternative approach is to treat technology explicitly instead of implicitely and to introduce a time element into the trade model. The observed patterns of comparative advantage result from interactions that incorporate a time element and are more complex than those specified by the traditional factor proportions models, Hirsch indicates. Hirsch also refers to the first approach as the 'neo-factor-proportions approach,' and to the second approach as 'neo-technology approach.'

The neo-factor-proportions approach is very close to neo-classical trade models, and the neo-technology approach is a recent development that treats technology in a dynamic fashion.

On the other hand, traditional trade theorists pay less attention to the international flow of technology. Implicitely, they treat technology as part of capital that will automatically flow from capital-rich to capital-poor countries. It will ultimately result in something like factor-price equalization. Actually, the approach that technology is part of capital, will aggravate the situation of capital disparity. Then the critical trade theorists take technology as a single factor for transfer. Both theories have two limitations: First, they treat capital as a homogeneous good. Second, the market situation is based on competition models in which monopoly nature in the process of technology transfer is ignored.

Constantine V. Vaitsos [41] and Raymond Vernon [42] indicated that technology transfer takes place through a market process. Technology is rarely transferred by itself, but sold in a package in which it contains not only money capital, but also human capital. Technology transfers often occur within a monopolistic structure, and may be intended to preserve monopolistic returns.

3. The Choice of Technology, Productivity and Factor Proportion

The choice of technology is influenced by economic, socio-cultural, behavioral and informational variables. These are several criteria in the consideration of choice of optimal technology. The ultimate goal in the choice is to minimize production cost; of course, there are other variables which are important in the choice, such as maximizing labor productivity, reducing the capital-output ratio, selecting capital or labor-intentive technology, but they are not goals in themselves. Gouverneur [43:1] defines the choice of optimal technology as "Given the 'state of technique' (or production function) and the relative prices of the factors of production involved, the optimal technique for a given firm may be defined as that particular combination of factors which minimizes the firm's production cost at its long-run equilibrium level of output. Under the hypothesis of profit maximization, this equilibrium level of output is the level where long-run marginal revenue and cost are equal to each other." The above equilibria and optimal technology are based on comparative statics which assumes a given change in the conditions that determined an initial equilibrium position and shows the ultimate consequences of this change when all other things are kept constant.

This equilibrium of the firm is influenced by relative factor prices, ruling technology and demand conditions in the market. A change in the absolute prices of factors relative prices being unchanged, and a change in demand, both give rise to a new position of the marginal cost curve, the scale of output changes, without any effect on the shape of isoquant and isocost lines. If relative factor prices change, the shape of isocost lines also change. If technology advances (neutral type), it will bring the isoquant curve closer to the origin. If the technology progress

is non-neutral, then the isoquant curve will not only be brought closer to the origin, but the shape of the isoquant curve will also be changed.

The changes in technology and factor prices have at the same time an induced effect upon output level. Therefore, a change in relative factor prices will have a substitution effect along an isoquant curve and a scale effect along the scale line. (Fig. 6).

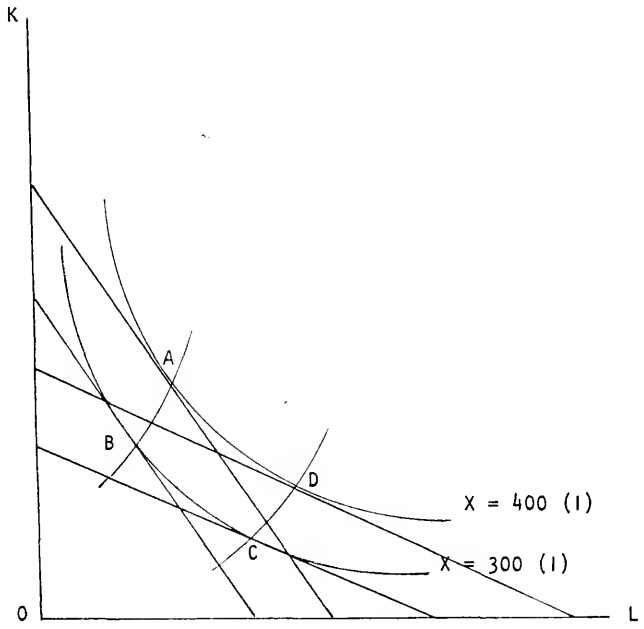

Figure 6: Substitution and Scale Effects

AD and BC = Substitution effect
AB and DC = Scale effect
X = the equilibrium value of output, given cost and demand conditions
I = state of technology

A change in technology (neutral in nature) also has two effects, a progress effect along the progress line, and a scale effect along the scale line (Fig. 7). If the technology change is non-neutral progress, it will also have a substitution effect in addition to progress effect and scale effect. Whereas a scale line indicates the least-cost combinations of factors needed to produce varying volumes of output in a given state of technology, a progress line shows the least-cost combinations of factors needed to produce a given output in varying states of

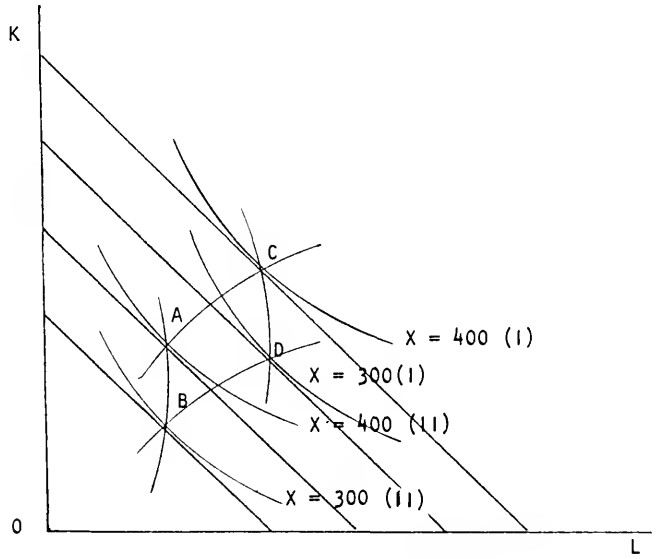

Figure 7: Progress and Scale Effects

AB and CD = scale lines
AC and BD = progress lines

technology. In the above two cases, relative factor prices are held constant.

The above delineation of effects shows an ambiguity concerning their magnitude, but these effects could be generally classified as the effect which moves along the isoquant curve (or along the production function) and the effect which changes the position of isoquant (or

changes production function). As far as the scale is concerned, it may derive from an autonomous change in demand conditions in the market, so as to affect the output level, or it may be induced by changes in factor prices or technology, or may be caused by the combined influences of all these three sources.

This leads to some problems of capital intensity. The substitution effect is more precisely the relation between capital cost and labor cost.

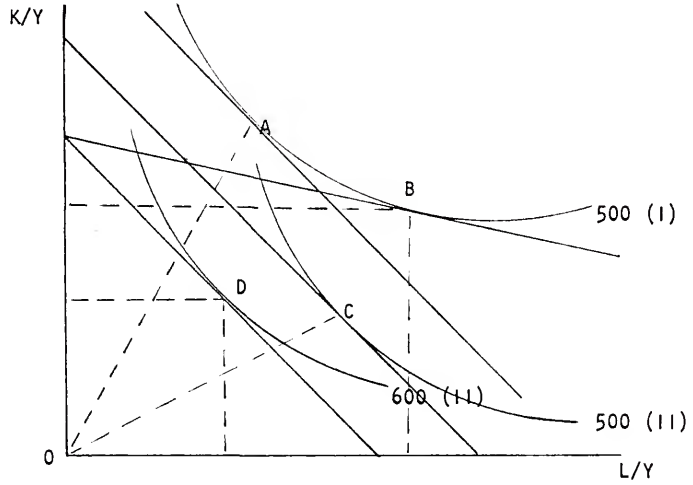

Figure 8
The Combined Effects of the Substitution, Scale and Progress Effects

AB = substitution effect
AC = progress effect
CD = scale effect

Here we use input efficients instead of absolute factor quantities for any given output along the axes

Labor cost may be defined as direct wages and indirect charges; capital cost may be defined as a function of the price of capital goods, the interest rate, the risk involved, and the expected life of equipment. Improvement in capital goods or lowering the interest rate of the capital, may lead to cheapening of capital goods relative to labor. In the long-run, however, due to the technology progress which will improve capital

goods, the relative cost of capital will go down and the cost of labor will go up, so that the capital intensity will go up in either case. But the ultimate result depends upon the elasticity of substitutions between capital and labor (if only two inputs), the magnitude of the rise of the labor cost, and the production function.

It is very likely that the scale effect has an impact upon the scale of output and capital intensity, but it will depend upon the long-run cost curve of the production function which tends to be L-shaped. The final impact of scale effect on factor intensity depends upon the phase of returns (increasing, constant or decreasing). If in increasing returns, rise in K/L, the L/Y must decline. In a constant return case, if one coefficient goes up, the other must go down; so if K/L rises, L/Y must go down.

There are some controversial issues on the progress effect. Some regard technological advance as a residual for a given scale and a given price ratio, e.g., Salter [44] takes the position that "the common case seems to be that of technical advances which save all factors simultaneously" though not necessarily in the same proportion. In reality, it is difficult to state a priori whether the progress effect tends to save more of one factor than of another. But at least, he indicates that there are somewhat factor intensity problems, just because of no way to separate them, whether there is a labor-saving bias in technology progress or not. Salter further pointed out that the difficulties in separating and assessing such biases, as these are complex interactions between the character of technical advances and factor substitution. The only approach is to ask where there is anything inherent in the character of technical advance which is likely to lead to such a strong labor-saving

bias. This arises out of the theory of induced inventions as set out by Hicks. It indicates that when labor becomes dearer relative to capital, the researcher will pay more attention to labor-saving technologies, but Salter refuted this by saying that when labor costs rise, any advance that reduces total cost is welcome; there is no reason to assume that attention should be concentrated on labor-saving techniques, unless, because of some inherent characteristic of technology, labor-saving knowledge is easier to acquire than capital-saving knowledge.

In short, technology developed is actually not independent of factor prices. Technological progress tends towards increasing K/L and possibly increasing K/Y too. The progress of knowledge is in principle independent of factor prices,[43] in which case possible biases (towards increasing or decreasing K/L) are more random than systematic (as in the case with Hicks's autonomous inventions).[45]

In the same spirit, there is no reason to state a priori that technology progress would secure factor savings at high levels of output only. Of course, it is in principle; in reality, the higher volume of output, the better fit for mass production and labor-saving technology.

From a purely theoretical framework, we may conclude that when the output increases, L/Y must necessarily decline, all the three effects acting in the same direction; the intensity of decline will be greater, the stronger each of the three effects. A rise in K/L is almost certain: both the scale effect and substitution effect strengthen it; capital-saving bias is almost very seldom occurring in such expansion of output. Concerning K/Y, if there is a strong progress effect, it will decline; substitution effect pushes it up; while the scale effect is determinate

only in the phase of constant unit cost. Therefore, the higher the scale effect and substitution effect, the higher the K/Y. On the reverse, the stronger the progress effect, the weaker the K/Y.

In the case of declining output, a decline in L/Y is likely, since both the substitution effect and the progress effect work in that direction. A rise in K/L is not likely because the substitution effect may be offset partly by the scale effect. The progress effect is still uncertain. K/Y is still increased by the substitution effect and reduced by progress effect, but the scale effect will now tend to reduce it.

Based on the above analysis, we may tentatively summarize that the relative labor cost will rise. Some saving on both labor and capital is likely because of technological progress. The scale effect has a positive effect on K/L. Long-run average cost curve exhibits decreasing unit cost first and constant afterwards. Finally, a decline of L/Y is certain. A rise of K/L is almost certain. The K/Y is determined by the relative strength of each of the three effects. Substitution and progress effects pull in opposite directions, while the influence of the scale effect depends on the phase of returns. [43]

Based on the above theoretical analysis, it seems that the entrepreneur always benefits from the optimal techniques when he makes the choice. In fact, the optimal technology may not exist due to reasons such as division of labor in the choice process and differences in characteristics of DCs and ACs, especially in market size and relative factor prices facing the entrepreneurs who must make the choice. Given these conditions, the entrepreneur in the DCs is in a dilemma and unable to achieve optimal combination of factors which will minimize the production cost of given output, technology, factor prices and market size; and will

have to select suboptimal technology. The dilemma is that the technology required and suited to both local market and relative factor cost conditions does not embody the modern technology. On the reverse, the modern technology is unsuited either to the local price ratio or to the local market size and market conditions. Furthermore, the old technology which is suited to the local conditions either to the factor price ratio or market size and market conditions does not exist in either DCs or ACs because this type of equipment embodied with old technology has ceased to be produced on the ground that the marginal cost of production exceeds the marginal revenue. The local entrepreneur is forced to choose the modern technology which is unsuited to the local conditions.

The modern technology which is unsuited to the local conditions does not mean that the modern technology is inferior to the old technology which is suited to local conditions. The modern technologies applied to the local economy may be more economical than the older ones. Their advantage over the older ones may be reduced, but not necessarily cancelled. Their advantages are increased if the older technologies themselves are also unsuited to local conditions, which is very likely because the local conditions are not in a static but dynamic evolution. Under this dynamic evolution which has been exemplified in the DCs, the older technologies have also been replaced with newer ones. Therefore, the argument that the modern technologies are unsuited to the local conditions should be abandoned and the older ones should be brought in to suit the local conditions is a big question. We should pay attention to the economical benefits finally derived by adopting the modern technologies, not just the suitability of modern technologies to the local conditions because the suitability is not the final goal in itself in the choice of technology.

The comparative advantage on economical grounds is the final target in the process of choice.

The choice between a modern and an old technology is influenced by the gap in relative factor prices and market conditions between DCs and ACs and by the magnitude and pattern of technological progress. For a given technology, the larger the gap in relative factor cost and market conditions between the two countries, the smaller the superiority of the modern technology; the narrower the gap, the more likely the adoption of a modern technology. For a given gap in relative factor prices and market conditions, the larger the improvement in technological know-how, the more likely the adoption of a modern technology.

There are two different opinions on the labor efficiency, though labor is generally assumed to be less efficient in DCs. Objections to this assumption usually refer to specific tasks for which it is argued that workers in DCs are as efficient as the workers in ACs. This leads to the suggestion that the firm in the DCs should innovate more capitalistic processes in order to offset the relative inferiority of labor.

Hirchman's [46] view is that labor performance in both DCs and ACs is almost identical when capital-intensive technologies are used, but it diverges considerably for labor-intensive technologies; while Enke's [47] is that labor in DCs is always inferior to some constant degree, irrespective of the capital-intensive or labor-intensive technologies used. Both authors are aware that their assumption of similar price ratio in both DCs and ACs are unrealistic. Gouverneur's [43] view is that if labor is inferior in DCs, the appropriate technologies for DCs is less labor-intensive than a simple of comparison of factor price ratio, and he further suggests that there is no need to adopt or innovate a

specific technology; all that is required to minimize cost in DCs is to adopt the existing modern technology which is more capital-intensive. It is more likely that a selective approach would be more appropriate than the above radical approaches. The selective approach will take care of both problems in meeting local conditions and adopting modern technologies as well as the priority problems set up by the government. Accompanying the selective approach is the adaptive process: not only dealing with the transferring of technologies from the ACs, but analyzing the adaptability of the technologies developed in ACs. The adaptive processes will change the optimality of a technology to meet the local factor prices and market size and market conditions.

From pure combinations between old and modern technologies which existed both in DCs and ACs, Gouverneur indicates that if modern technology is unsuited to the local factor price ratio only, input coefficients will be the same in both DCs and ACs. Referring to Fig. 9, the fact that the modern technology is unsuited to the local price ratio OD/OD' prevents the entrepreneur from achieving the optimal combination represented by point N'. But once the entrepreneur has decided to adopt modern technology P, his (suboptimal) input coefficients will be the same as the optimal coefficients of an entrepreneur adopting P in the ACs to produce the same quantity X = 1000.

Suppose OD/OD' represents the local price ratio, OA/OA' represents the price ratio prevailing at the ACs. N is the technology suited to the local price ratio at time t_1 in DCs. N' is the technology suited to the local price ratio at t_2 in DCs. P is the technology suited to the price ratio (which labor cost is higher) at t_2 in ACs.

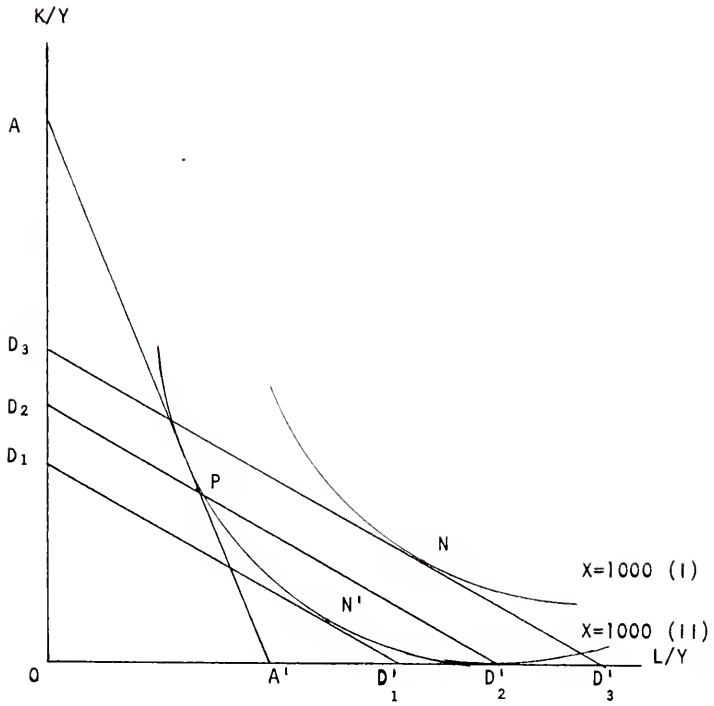

Figure 9
Combinations of Technologies

If the modern technology is unsuited to the local market size, input coefficients will differ between the two countries due to the fact that only half capacity of the modern technology can be used in the DCs. So Gouverneur concludes that since suboptimality with respect to the factor cost ratio does not affect the actual coefficients of the firm in the DCs, this type of suboptimality and possible changes in its degree between t_1 and t_2 can be ignored. All that is needed is to consider the changes in the modernity of the technologies successively adopted. But from the adaptive process point of view, we feel that it can not be entirely ignored. Gouverneur continues by saying that suboptimality with respect to market size cannot be ignored, since it affects the actual coefficients of the firm in DCs.

There are several possibilities that can happen in the transfer of technology from ACs to DCs. The first transition possibility is from a modern technology adapted by the DCs in the first period to a modern technology developed in the ACs in the second period (that means from T11 to T22), T22 as compared to T11 is characterized by a decline in L/Y and a rise in K/L, while K/Y may be higher or lower, based on the assumption that the degree of suboptimality with respect to the market size does not vary. The second transition possibility is from an old technology to an old technology (from T10 to T20), T20 compared with T10 in much the same way as T22 to T11, only the intensity of the decline of L/Y and of the rise of K/L may be weaker. The third transition possibility is from an old technology to a modern one (from T10 to T22). The intensity of the three effects will be much stronger, and the decline of L/Y and the rise of K/L will also be stronger. K/Y still depends on the respective strength of the three effects. The fourth transition possibility is from a modern to an old technology (from T11 to T20). The input coefficients will change a little or not change at all if T11 and T20 are developed at the same period. If T20 is developed earlier than T11, a reverse effect will happen to cause a rise in L/Y and a decline in K/L, the changes in K/Y are still indeterminate.

Now we turn to the question of the degree of suboptimality with respect to the market size. For any technology, the unused capacity affects the coefficients. The K/Y will rise due to the output decrease and the capital is partially fixed. L/Y will rise due to part of the labor also being fixed. Unused capacity usually increases K/Y much more than L/Y, so K/L is also increased.

In short, the direction of changes in L/Y, K/L and K/Y is generally about the same in DCs as in ACs because the modern equipment adopted in DCs is developed in ACs. Only one exception is that if the transition possibility is from a modern technology to an old one which will cause the L/Y to rise and the K/L to fall. The intensity of the changes is determined by the conditions existing in both DCs and ACs.

In reality, the direction of changes in input coefficients is largely affected by the previous transition experienced. The choice of technology for transfer is determined by the type of technology itself (general, system specific or firm specific), by the magnitude and pattern of technological progress (the 'magnitude' refers to the position change of production function, 'pattern' refers to the change of the production function itself), by the relative factor cost and by the market conditions prevailing both in DCs and ACs.

The relative factor cost determines the rate of replacement investment. In other words, a fall in either the interest rate or the price of capital goods increases the rate of replacement investment due to cheaper capital cost. Conversely, a rise in wage rate increases the operating costs of old-fashioned plants and machines so as to induce earlier replacement. So the higher the relative cost of labor in DCs, the faster the transfer of technology from ACs to DCs.

The profit rate constitutes a strong incentive to reduce cost and to expedite the transfer process by importation of modern technology. External pressure and avoidance of risk also exerts a powerful influence on the transfer process. Poor efficiency of labor will raise L/Y, thus lowering K/L. Improving labor efficiency by training and education will reduce L/Y including the efficiency of managerial and administrative

operation so that better organization and capacity utilization also can be improved. In sum, all input coefficients will decline by the improvement of labor efficiency because of production being increased and cost reduced.

In sum, the above analysis of technological transfer and choice of technology by Gouverneur are from pure theoretical points and expressed more or less in static conditions. From practical points of view, they have ignored the adaptive nature of technology which will alter the characteristics of static conditions in technological transfer. It does not mean that the analysis done by Gouverneur is useless. On the contrary, it gives us a basic theoretical foundation and a good starting point for economic analysis of the process of technological transfer. The adaptive process is a very complex phenomenon wherein cost and benefit analysis will be the pillars. It does not mean that all technologies are adaptable. Under certain circumstances, adapting technology from ACs is more economical than merely adopting; but some technologies are not adaptable in themselves, and the cost of adaptation will far exceed the benefit derived from the adaptation. The adaptability of technology generally depends upon the nature of the technology itself, the characteristics of giving and receiving countries, including their factor prices, factor endowment, market size, and the conditions prevailing in ACs and DCs, especially the willingness and adaptive capability, will be the decisive factors for a successful adaptation of technology.

4. Types of ITT

Technology can be transferred between nations in a variety of ways. Generally, it is roughly classified into two types of technology, proprietary and nonproporietary technologies. According to Dunning,[48] proprietary technology is mainly transmitted by (1). direct investment of multinational corporations and (2). licensing of patents, and a variety of manufacturing or technical service agreements, and some kinds of consultancy services. Nonproprietary technology includes not only the results of new knowledge contained in the technical literature, but (1). direct purchases of hardware or services, such as new machinery and equipment, test devices, computer software, and related consulting services. (2) technical-service activities backing up these sales or introducing new products (3). demonstrations of modern management technologies at seminars, conferences, exhibitions, etc. (4) technical assistance to suppliers and customers on special problems (5). observation and imitation of nonproprietary technologies (Quinn[49], 1968).

Balasubramanyan[50] classified the mechanisms of technology transfer into three larger categories such as (1). technical collaboration agreements, (2). direct foreign investment, and (3). hybrids which include joint ventures and technical collaboration agreements with minority of foreign equity. Each form has merits and demerits. The choice of the mechanisms depends on the nature of the technology, the stage of economic development and the stage of technology development, international reserve positions, and government policies concerning technology transfer.

According to Hymer [51] and Ozawa, [52] when the foreign market is imperfect (that is, when only a few firms exist) a bilateral monopoly problem makes co-operation through licensing difficult. On the other hand, when the foreign market is highly competitive (that is, when many potential buyers of technology exist) licensing is almost certain, since the market mechanism fully appropriates the returns to the seller. Hymer generalizes that it is the market imperfection, therefore, that leads the possessor of the technical advantage "to choose to supersede the market for his advantage."

One of the advantages of proprietary technology transfer mechanisms is that it provides the recipient with a wide range of technological and managerial know-how. The available know-how sometimes applies to all the phases of the business operation, such as pre-capital investment preparation, capital investment, maintenance, production, quality control, management, and marketing know-how, including evolution of technology to meet the competition and the rapid technological innovation which is usually at the dictates of the parent company. But the big advantage of the mechanisms of non-proprietary transfer is the freedom of choice, because the proprietary know-how restricts the availability of technology available and prevents their full exploitation of available technology. This introduces monopoly and technology rigidity by the technology holders such as multinational corporations. The technology suppliers exercise monopoly power by leaving room for physical equipment purchases to be tied to maintenance, repairs and the purchase of ancillary equipment so as to prevent the use of these services from a cheaper source.

In short, the existing mechanisms of technology transfer are inefficient. Available technologies do not move freely across national borders. Allen, Piepmeier, and Cooney [53] examined the concept of the international Technological Gatekeeper. This is an intermediary whose primary function is the acquisition, effective transfer, and dissemination of foreign technology by way of integrating the internal network of domestic users to whom the required information can be delivered and the external channels of foreign information sources. This is almost the same idea as discussed in Chapter III, the concept of the interface model of international technology transfer. The only difference is that our suggestion is more appropriate and mature by adapting and taking advantage of the latest concept of computer-based management information system. The DCs, therefore, should foster the concept of the interface model as proposed, set up the information centers or MIS of technology transfer and open up all channels for expediting technology transfer that is the key factor for rapid economic growth.

CHAPTER V.
TECHNOLOGY PROGRESS

Since World War II, the importance of technology has been widely recognized as an important factor for the industrialization of ACs and DCs as well. Brown [54:1] states, "Not since classical economics has it been found by non-Marxist economists to play such a crucial role in the determination of production movements and in the distribution of income. This is probably attributable to economic growth of variable technologies which is found to be as important as - or in some cases even more important than - the traditional labor and capital factors." Brown quoted an article by Moses Abramowitz [55:5-23] by saying, "There be found that almost the entire increase in net product per capita was associated with the rise in something other - subsequently called the 'Residual' - than the inputs of the physical stock and the services of labor." As mentioned before, only one-eighth of the cumulative upward shift in the production function of U. S. non-farm sector between 1909 and 1929 was attributable to the increased capital per manhour, and seven-eighths was attributable to technology progress according to Solow's study.

Even though the present state of art in measuring technological progress is still in its infancy in terms of conclusive results and each existing method has its deficiencies, these do not negate the general conviction that technology progress is fundamental in explaining the complex phenomena of modern economic development, such as structural change, technology break, severe cyclical problems, factor intensity, etc.

1. Production Function

Production function may be defined as the technical relationship between a given value of output obtainable from various combinations of inputs or as Murray Brown [54:1] defines it, "A production function expresses the relation between the maximum quality of output and the inputs required to produce it, and the relation between the inputs themselves." The parameters of the production function represent characteristics of the abstract technology in use. The production function is a fiction fabricated by marginalist economists but can also be derived from purely engineering data. It is often useful in producing hypotheses and enables the economists to analyze a wide variety of problems, e.g., determination of technology progress, income shares, factors affecting economic growth, etc. Brown continues to explain that the production function and its relationship between outputs and inputs and between inputs themselves are determined by existing technology. There are generally four types of abstract technology, i.e., the efficiency of the technology, the degree of economies of scale, the degree of capital intensity of a technology, and the ease with which capital is substituted for labor.

The production function models were developed by the neo-classical economists, and there are some necessary criteria which must be satisfied by these models. These criteria can be represented graphically by a set of isoquants which must be non-intersecting, downward sloping curves convex to the origin. Each isoquant represents the various combinations

of inputs for producing a given output. The above criteria can also be expressed by symbolic relationships under existing technology, e.g. a general production function or surface of the output (Y) in terms of two inputs, capital (K) and labor (L), (assuming only two inputs in this simple production model), can be expressed as $Y = f(K,L)$. Non-interacting means that an isoquant is the maximum output obtainable from a given combination of resources. Downward sloping means that the slope of the isoquant must be negative. Now with $Y = f(K,L)$, the total differential of Y and setting $dy = 0$ means that $dy = f_k dK + f_L dL = 0$ and yields:

$$-\frac{dK}{dL} = \frac{f_L}{f_k} = \frac{\partial Y/\partial L}{\partial Y/\partial K} = \frac{MP_L}{MP_k} = MRTS$$

Marginal rate of technical substitution is the ratio of the marginal product of labor to the marginal product of capital, in the production of output, and the negative slope of the isoquant $-(dK/dL)$ is defined as the marginal rate of technical substitution.

Convexity to the origin for the isoquants means that the MRTS of labor for capital decreases as labor is substituted for capital, and the slope of the isoquant approaches zero as labor increases. This limiting condition is known as the principle of diminishing marginal rate of substitution between factor inputs and is closely linked with the definition of the elasticity of substitution.

Elasticity of Substitution estimates the ease with which capital is substituted for capital and is defined as the proportional change in the relative factor inputs to a proportional change in the marginal rate of substitution (or proportional change in the relative factor price ratio). Symbolically, the elasticity of substitution (σ) may be expressed as:

$$\sigma = \frac{\partial(K/L) \ / (K/L)}{\partial(f_k/f_L) \ / (f_k/f_L)} \qquad \text{or} \qquad \sigma = \frac{\partial(K/L) \ / (K/L)}{\partial(P_L/P_k) / (P_L/P_k)}$$

The level of output along an isoquant and the elasticity of substitution (σ) must be a positive value. The optimal point of production for a firm is where the isocost curve is tangent to the isoquant curve and where the MRTS is equal to the input price ratio at Point A. (Fig. 10). It can also be conceived as a measure of the similarity of factors of production in terms of technology. It may vary from one combination of factors to another. The elasticity of substitution is inversely related to the curvature of the isoquant curves. When $\sigma = 0$, the isoquant are rectangular corners and the factor inputs are not interchangeable; On the other hand, when σ = infinity, the isoquant are straight lines with negative slopes equal to one and the factor inputs are perfect substitutes for one another, and the output may be produced with only one factor input, capital alone or labor alone. When σ equals any other positive value, the isoquants are rectangular hyperbolas and the capability of the input factors for substitution corresponds directly to the varying value of σ. If σ is unitary, the substitution between the factor inputs will be one to one.

Capital Intensity measures the magnitude of the capital and labor ratio (K/L). Here we are primarily concerned with the technological conditions of the production, not the relative factor supplies. It is an important indicator for it affects the MRTS and output as well. In case of two firms located in a market and facing identical factor supplies and input prices, the firm with the higher σ will have a higher

percentage change in capital intensity when a change in input price ratio occurs. When the elasticity of substitution (σ) changes, it will also change the marginal product of one factor input relative to the other factor inputs unless there is a corresponding proportional percentage change in capital intensity. For any given technology, the capital intensity characteristics usually do not vary in response to current changes in output or relative factor prices because it is part of the structure of the existing technology.

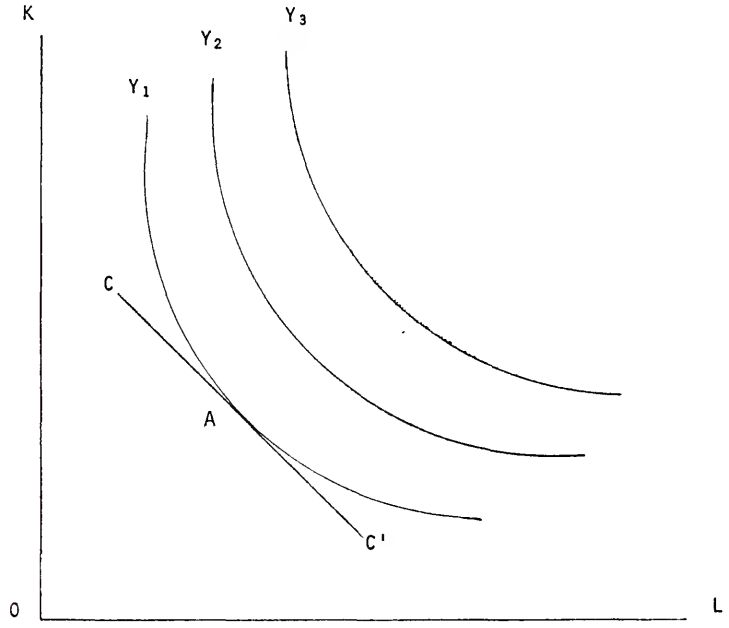

Figure 10: Neoclassical Criteria of Production Function

Income distribution is defined as the income share of factors. When the prices of an input factor changed, the income share of the factor input will also be changed. Mathematically, the capital share of income is $K\ P_k$ and labor share of income is $L\ P_L$, the ratio of capital share of income to labor share of income is

$$ISF = \frac{K\ P_k}{L\ P_L} = \frac{K/L}{P_L/P_k}$$

Taking the logarithm of ISF, we obtain

$$\log(ISF) = \log(K/L) - \log(P_L/P_k)$$

Taking the derivative of log(ISF), we get

$$\partial \log(ISF) = \partial \log(K/L) - \partial \log(P_L/P_k)$$

We may recall that the elasticity of substitution (σ) may be written as

$$\sigma = \frac{\partial(K/L)\ /\ (K/L)}{\partial(P_L/P_k)\ /\ (P_L/P_k)} \qquad \frac{\partial \log(K/L)}{\partial \log(P_L/P_k)}$$

Rearranging terms we get

$$\partial \log(K/L) = \sigma\ \partial \log(P_L/P_k)$$

Substituting this equation into the derivative of log(ISF), we obtain

$$\partial \log(ISF) = \sigma\ \partial \log(P_L/P_k) - \partial \log(P_L/P_k) =$$

$$(\sigma - 1)\ \partial \log(P_L/P_k)$$

If $\sigma = 1$, the ratio of capital share of income to labor share of income (ISF) will be unchanged, no matter if the input-price ratio of the factor inputs changed or not. If $\sigma > 1$, the ratio of capital share of income to labor share of income will be positively related to the changes in input-price ratio. An increase in the price of labor relative to the price of capital will lead to an increase in capital share of income. On the other hand, if $\sigma < 1$, the IFS will be negatively related to the changes in (P_L/P_k). An increase in labor prices relative to capital prices will lead to a decrease in capital share of income. Here it is indicated that the value of elasticity of substitution will determine the income distribution and watching the changes of value of σ will give us the information of technology progress. The higher the σ, the easier the substitution between factor inputs and also the higher capital intensity will be.

2. Abstract Technology

There are generally four kinds of characteristics in a production function, and we call them abstract technology. As mentioned, outputs are produced with inputs under existing technology and their relationships are expressed in a production function. The technology is thus embodied in a production function and can be expressed in terms of it. In order to properly define a technological progress in terms of the four characteristics in a productive function, it would be necessary to briefly introduce each of the four characteristics which are usually expressed as parameters in a production function. They are the efficiency of the

technology, the degree of economies of scale that are technologically determined, the degree of capital intensity of a technology, and the ease with which capital is substituted for labor.

The efficiency of a technology determines the output given the other characteristics, but it will not affect the relations of inputs to inputs. It acts as a scale transformation of inputs into output. An increase in the efficiency characteristics indicates a shift in the efficiency of the technology in the production function so as to increase output, but the production function itself will not be changed, only the total output level will be augmented.

The economics of scale is defined as measuring the impact of a proportional change in inputs in terms of a proportional change in outputs excluding the impact of the scale of operation of an organization. If output is increased by the same proportion as input, the firm is in a constant returns to scale; if output is increased by a larger (or smaller) proportion as compared to that of input, the firm enjoys increasing (or decreasing) returns to scale. Whether or not the firm benefits from the technological progress depends on the scale of operations.

The elasticity of substitution estimates the ease with which capital is substituted for labor and is defined as the proportional change in the relative factor inputs to a proportional change in the marginal rate of technical substitution (or the proportional change in the relative price ratio). It also can be conceived of as a

measure of the similarity of factors of production in terms of technology. It may vary from one combination of factors to another.

The Capital Intensity measures the magnitude of the capital and labor ratio (K/L). Here we are concerned primarily with the technology requirements of the production process, not the effects of relative factor supplies. It affects the marginal rate of technical substitution and total output as well.

3. Technology Change

So far there is no simple way to measure technology progress because technology itself is a very elusive concept. Thomas and Le Heron [56:323] said, "A study of the term technology change reveals that it is an exceedingly elusive and complex concept." Mansfield[57:372] also indicated, ". . . economists have been led to inquire more seriously into the process of international technology transfer. Because of the complexity of this process, and the fact that it has received relatively little attention in the past, our knowledge of it is still rather meager . . . . " Here we will define a technological change in terms of changes in the abstract technologies. In production theory, there are generally two types of technological change, neutral or non-neutral. Neutral technological change does not actually alter the production function, but only shifts the total output level. It neither saves nor uses labor. It also does not change the marginal rate of technical substitution, nor the slope of the isoquant. The neutral technological change is influenced by the efficiency of the technology and

economies of scale. Non-neutral technological change is biased toward capital-using or labor-using. Both marginal rate of technical substitution and the slopes of the isoquant are changed under non-neutral technological change. The elasticity of substitution and the capital intensity will constitute the major sources in determining non-neutral technological change. We may say that the elasticity of substitution is technology determined through capital intensity. An increase in capital intensity increases output if labor is growing more slowly than capital; conversely, an increase would reduce output in case labor is growing more rapidly than capital. This is an important point when facing choice of technologies. An increase in the elasticity of substitution always raises the rate of increase of output because the elasticity of substitution is closely related to capital intensity and the efficiency of technology.

In Chapter VII, the three characteristics: technological change, elasticity of substitution and capital intensity will be the most important indicators for our empirical analysis, and the four abstract technologies interacting with the changes in factor endowments determine the growth of output and distribution of income.

In measuring technological progress, the concept of production function and elasticity of substitution are important criteria. The Cobb-Douglas model and the Constant Elasticity of Substitution model of which Cobb-Douglas model is a special case will be applied for this purpose.

4. The Cobb-Douglas Production Function*

The Cobb-Douglas model proved to be useful at an aggregate level for a rough understanding of the changing importance of the 'residual' as a source of manufacturing growth indicated by Jorge M. Katz. [58] The popular form of the Cobb-Douglas production function with two factors can be written as: $Y = A L^{\alpha} K^{\beta}$ where Y = output, L = labor input, K = capital input, A = residual (technological progress), α = elasticity of production with respect to labor, and β = elasticity of production with respect to capital. The neoclassical criteria are as follows: The marginal productivities are positive.

$$\partial Y/\partial L = \alpha (Y/L) > 0, \text{ If } \alpha > 0, \quad \partial Y/\partial K = \beta(Y/K) > 0, \text{ If } \beta > 0$$

$$\alpha = \frac{\partial Y/\partial L}{Y/L} = MP_L/AP_L, \qquad \beta = \frac{\partial Y/\partial K}{Y/K} = MP_k/AP_k$$

The marginal products decrease

$$\partial^2 Y/\partial L^2 = \alpha (\alpha-1) Y/L^2 < 0, \text{ If } \alpha < 1$$

$$\partial^2 Y/\partial K^2 = \beta (\beta-1) Y/K^2 < 0, \text{ If } \beta < 1$$

*The derivation of Cobb-Douglas and CES production function are omitted here. Please consult 54, Brown, 1966, pp. 192-196.

The sum of the elasticities of production represent the total percentage change in output due to all inputs. In the Cobb-Douglas model, the sum $\alpha + \beta = 1$ is characterized by constant returns to scale. Since

$$\sigma = \frac{\partial \log(K/L)}{\partial \log(MRTS)} \qquad MRTS = \frac{\partial Y/\partial L}{\partial Y/\partial K} = \frac{\alpha(Y/L)}{\beta(Y/K)} = \frac{\alpha}{\beta}(K/L)$$

$$\log (MRTS) = \log (\alpha/\beta) + \log (K/L)$$

$$\partial \log (MRTS) = \partial \log (\alpha/\beta) + \partial \log(K/L)$$

Because α/β is a constant value, the change in the log (α/β) is zero, so

$$\frac{\partial \log (K/L)}{\partial \log (MRTS)} = 1 = \sigma$$

The elasticity of substitution (σ) is unitary, and it guarantees that the relative distribution of income between capital and labor will remain constant under unchanging existing technology, when there are changes in the relative supply of factor inputs. Of course, this restriction of unitary elasticity as a priori does not meet the real conditions of the market, such as inter-industry differences in the elasticity of substitution between factor inputs, factor intensity reversals and a change in relative input prices. It was this restriction of unitary elasticity that led to the development of the constant elasticity of substitution (CES) model of which the Cobb-Douglas model is a special case.

In this Cobb-Douglas case, variations in three of the four characteristics of an abstract technology can be represented in the variation in the parameters of the production function A, α and β. 'A' parameter

indicates neutral technological change, as do equal proportion algebraic changes in α and β. Non-neutral technological progress is represented by a change in the ratio of α to β. It alters the MRTS, factor-saving or factor-using technological progress being denoted by the direction of change of the ratio (α/β).

The basic Cobb-Douglas model with constant returns to scale, and disembodied technological progress can be expressed as [58]

$$Y = A(t)\ K^{\alpha}\ L^{(1-\alpha)} \qquad (5.1)$$

where Y = output at constant price, L = labor in terms of physical units of labor employed, A(t) = an index of total factor productivity, α and $(1-\alpha)$ = elasticity of output with respect to capital and labor respectively. Differentiating equation (5.1), the rate of growth of output can be written as

$$\dot{Y}/Y = \dot{A}/A + (1-\alpha)\ \dot{L}/L + \alpha(\dot{K}/K) \qquad (5.2)$$

$\dot{Y}/Y$ = relative rate of growth of output

$\dot{K}/K$ and $\dot{L}/L$ = relative rates of growth of capital and labor inputs

α and $(1-\alpha)$ = elasticity of output with respect to capital and labor

Dots indicate time derivative ($\dot{Y} = dY/dt$)

Professor R. Solow [59] has shown that equation (5.2) permits calculation of the rate of growth of total factor productivity and of that part of the rate of growth of output that can not be explained by weighted growth of capital and labor as conventionally measured. This is a catch-all residual which combines all factors influencing the rate of growth of output rather than the weighted rates of growth of capital and labor. This approach assumes constant returns to scale and perfectly competitive factor and commodity markets, the shares of capital and

labor in output become indicators of the elasticity of output with respect to capital and labor.

Solow started by postulating an aggregate production relationship as $Y = f(K,L,t)$ with Y, K, and L defined as above, the variable 't' for the time in function allows for technical change, the function becomes $Y = A(t)\ f(K,L)$ (5.3)

The term A(t) measures the accumulated effect of production function shifts over time (i.e., the technical changes). Differentiating (5.3) with respect to time and dividing by Y, we obtain

$$\frac{\partial Y}{Y} = \frac{\partial A}{A} + A\ (\partial f/\partial K)\ (\partial K/Y) + A\ (\partial f/\partial L)\ (\partial L/Y) \qquad (5.4)$$

Assuming constant returns to scale and competitive markets, the share of capital (S_k) and labor (S_L) are indicated by their respective elasticity of output.

$$\alpha = S_k = \frac{\partial Y/\partial K}{Y/K} = \frac{MP_k}{AP_k}, \quad \beta = S_L = \frac{\partial Y/\partial L}{Y/L} = \frac{MP_L}{AP_L} \qquad (5.5)$$

From equation (5.4)

$$\frac{\partial Y}{\partial K} = A(\partial f/\partial K), \text{ and } \frac{\partial Y}{\partial L} = A(\partial f/\partial L) \qquad (5.6)$$

Inserting (5.6) into (5.5) and in turn inserting these into (5.4), we obtain

$$\frac{\partial Y}{Y} = \frac{\partial A}{A} + S_k\ (\partial K/K) + S_L\ (\partial L/L) \qquad (5.7)$$

With $S_k + S_L = 1$ (assuming constant returns) equation (5.7) becomes

$$\frac{\partial Y}{Y} = \frac{\partial A}{A} + S_K\ (\partial K/K) + \frac{\partial L}{L} - S_k\ (\partial L/L) \qquad (5.8)$$

Rearranging terms,

$$\frac{\partial Y}{Y} - \frac{\partial L}{L} = \frac{\partial A}{A} + S_k\left(\frac{\partial K}{K} - \frac{\partial L}{L}\right) \qquad (5.9)$$

Letting $y = Y/L$, and $k = K/L$, and noting that

$$\partial y/y = \partial Y/Y - \partial L/L, \text{ and } \partial k/k = \partial K/K - \partial L/L, \qquad (5.10)$$

Substitution (5.9) and (5.10), we simplify equation (5.9) into

$$\partial y/y = \partial A/A + S_k(\partial k/k) \qquad (5.11)$$

This is Solow's empirical model. In order to apply actual data into the model, what we need is output per worker (y), which is a function of capital per worker (k) and accumulated technological progress ($\partial A/A$). To find technological progress (residual), one needs only a series of output per worker, capital per worker, and the share of capital (S_k) which enable one to obtain a series of annual technological changes which can be used to compare with labor productivity to see how much is attributable to technological progress and how much to capital intensity for the growth of GNP per worker. This residual technological progress can also be averaged in whole or in subperiod to see whether there is any structural break. The trend indicated by this technological progress can be correlated with other economic indicators to see their inter-relationships, e.g., correlating with foreign capital to see the effect of foreign presence. By analyzing the evolution of technological progress, one can match it with government policy in various periods to see the impact of various policies. Application of the models will be discussed in Chapter Seven.

An unrestricted version of the Cobb-Douglas production function used in the least squares technique for estimation provides an independent

check on the result obtained from the basic Cobb-Douglas Model. In this new version model, the assumptions of constant returns to scale and perfect competitive factor and commodity markets were dropped. The elasticity of output with respect to capital and labor were left unconstrained to take any value. Technological change is still assumed to be disembodied and neutral. Professor Tinbergen [60] introduced an additional source of change in labor (and capital) productivity, which he called a rise in efficiency. This efficiency component is specified by an exponential $e^{\lambda t}$, so that the production function is

$$Y = A L^{\alpha} K^{\beta} e^{\lambda t} \qquad (5.12)$$

The logarithmic transformation of (5.12) can be estimated by least squares using time series data for output and capital at constant prices, and man-years of labor inputs. Where Y, L, K, α, β are defined as above, λ is an estimate of the annual rate of neutral technical progress. By this check, we can find out from the overall result of the least squares the approximations of the two models (basic model and unrestricted model), e.g., if the sum of the elasticities is not significantly different from unity, there would be no reasons for believing that the share of capital and labor in manufacturing output constitute poor approximations to the elasticities of output with respect to capital and labor.

A shortcoming of the Cobb-Douglas production function is that it has limited use except for roughly understanding the changing importance of the residual as a source of manufacturing growth at an aggregate level. There is no reason to believe that the elasticity of substitution should be fixed at unity, not allowing for interindustry differences in the

relative ease of substitution between factor inputs and for factor intensity reversals. Besides, lack of capital data at manufacturing sector level also limits itself for wide application. In reality, differences in the elasticity of substitution among industries may constitute the major cause of variations in pattern and rate of economic growth, and it can not be set a priori that the elasticity of factor substitution is irrelevant to the explanation of growth. Rather, in Chapter Seven, the elasticity of factor substitution will be used as a major indicator in the explanation of the pattern of expansion in the manufacturing industries. In the following section, elasticity of substitution between factor inputs will be relaxed to take any value between zero and infinity.

5. CES Production Functions

CES production function was developed independently by two groups (Brown [61] and Arrow et al. [62]) in the early 1960's. The elasticity of substitution is assumed to be a constant value determined by the existing technology; the constant is not restricted to any particular value a priori. The Cobb-Doublas model of production function, for three decades, was without serious rivals until the early 1960's.

It is well known that under Cobb-Douglas, assuming constant returns to scale and competitive conditions, the share of labor in output equals the exponent of labor (or real wage rate) in such relation, if

$$Y = A\, L^{\alpha}\, K^{(1-\alpha)} \tag{5.13}$$

is a production function homogeneous of the first degree, then we have

$$\alpha = \frac{\partial Y}{\partial L}\ \left(\frac{L}{Y}\right) = W\ \frac{L}{Y} \tag{5.14}$$

Where Y, L, K, are defined as above, W is money wage rate per man year, i.e., total labor costs divided by man-years. Setting (5.14) in the form of a regression model which can be written as

$$\log\ \frac{Y}{L} = -\ (\log\alpha) + b\ \log\ W \tag{5.15}$$

over 85% of the variation in productivity could be explained by the variation of wage rate alone in (5.15). [64] It has been shown that the coefficient b in 5.15 is, under competitive assumptions, equal to the elasticity of factor substitution. But K. Arrow, H. Chenery, B. Minhas and R. Solow [62] indicate that the above relationship comes from a more general production function of which Cobb-Douglas model and Harrod-Domar function as special cases where b = 1 and b = 0, respectively. This group of economists termed

this new function the CES production function that has a constant parameter of factor substitution. The world does not necessarily behave as a Cobb-Douglas model, nor a Harrod-Domar fixed proportions one. The elasticity of substitution is a technical parameter whose value should be determined by technology.

Brown and Popkin [61] indicated the following new production function in general form:

$$Y = g\,[ck^{-p} + (1+c)\,L^{-p}]^{-v/p}$$

where Y, L, K are defined as above. There are four parameters in the function:

g = efficiency of technology

p = substitution parameter which is the transformation, $p = (1/\sigma - 1)$ or $\sigma = 1(1+p)$ of the elasticity of substitution (σ).

c = distribution of income, indirect measure of capital intensity of technology defined in the range from zero to one.

v = degree of returns to scale (or degree of homogeneity of the function).

In order that the product be totally distributed among factor inputs, we may assume a production function having constant returns to scale, then the CES version, to interpret the elasticity between productivity and average wage rate as σ, we may write [58]

$$Y = g[ck^{-p} + (1-c)L^{-p}]^{-1/p}$$

Where neo-classical criteria are satisfied, marginal productivities are positive:

$$\frac{\partial Y}{\partial L} = (1-c)g^{-p}\,(Y/L)^{1/\sigma} > 0$$

$$\frac{\partial Y}{\partial K} = cg^{-p}\,(Y/K)^{1/\sigma} > 0$$

and the marginal products decrease:

$$\frac{\partial^2 Y}{\partial L^2} = (1/g)^p \left[(1-c)/\sigma\right] \quad (Y^{p+1}) \left[-1/\{1+(1-c)/c(k/L)^p\}\right] < 0$$

convexity of the isoquants:

$$MRTS = \frac{\partial Y}{\partial L} \Big/ \frac{\partial Y}{\partial K} = \frac{(1-c)}{c(K/L)^{-1-\sigma}}$$

differentiating the equation:

$$\frac{\partial(MRTS)}{\partial_L} = \frac{(1-c)}{c(K/L)^{-1/\sigma}} \left(\frac{-1}{\sigma}\right) \left(\frac{1}{L}\right) < 0$$

So the MRTS decrease as labor increases while holding capital constant. From the MRTS, we can see that the MP_L is higher than MP_k if the capital intensity indicator (c) is smaller than its complement (1-c). Therefore, the smaller the c, the more labor intensive the technology is as stated by Baca.[63] So the parameter 'c' is an indicator of income distribution as well as an indicator of capital intensity.

Estimation of CES Model:

Equation (5.16) when transformed to logarithmic form can be written:

$$\log Y = \log g - \left(\frac{v}{p}\right) \log \left[cK^{-p} + (1-c)L^{-p}\right] \qquad (5.18)$$

which may be used to estimate parameters g, p and c with actual data on output (Y), capital input (K), and labor input (L). Simple least squares techniques can not be applied directly with equation (5.18) because the term $[ck^{-p} + (1-c)L^{-p}]$ contains parameters, p and c to be estimated. There are several ways to estimate the parameters. One method that has been used is to adopt a side relation which contains p and c as parameters.

These estimates are then used to compute a new variable for the term in the last term of equation (5.18) which can then be directly fitted to data.

Another method is to estimate the parameter directly by fitting the equation, (5.16) without the side relation by a type of non-linear regression technique. But all of these methods of estimating the parameters of CES production function need fixed capital data. Unfortunately, such data are unavailable on an industry level. [58:42; 54:128-36; 63:48-9]

CES Production Function Without Capital Model

In the article by Arrow et al. [62] the authors show that by using marginal productivity of labor relation, the differential equation can be derived from the empirical relation between labor productivity (Y/L) and the wage rate (W) from equation (5.15) which permits the estimation of the elasticity of substitution between capital and labor. According to Katz,[58] if Y/L = y, the production function can be written

$$y = g[c(K/L)^{-p} + (1-c[]^{-1/p} \qquad (5.19)$$

Raising both sides of equation (5.19) to the p, we obtain

$$y^{p}\, g^{-p} = [c(K/L)^{-p} + (1-c)]^{-1} \qquad (5.20)$$

Assuming that the distribution of income is determined by competitive factor renumeration, and differentiating equation (5.17) with respect to labor we obtain the wage rate

$$\frac{\partial Y}{\partial L} = W = g(1-c)\ [c\ (K/L)^{-p} + (1-c)]^{-1} - \frac{1}{p} \qquad (5.21)$$

Substituting equation (5.19) into (3.21), we obtain

$$W = y(1-c)\ [c(K/L)^{-p} + (1-c)]^{-1} \qquad (5.22)$$

Then substituting (5.20) into (5.22) we obtain

$$y^{1+p} = g^{P} (1-c)^{-1} W \qquad (5.23)$$

Taking logarithms of equation (5.23) and dividing by (1+p), we get

$$\log y = \sigma \log g^{P} (1-c)^{-1} + \sigma \log W \qquad (5.24)$$

As P, C and g are assumed to be constants determined by the existing technology, equation (5.24) can be written as:

$$\log y = \beta_0 + \sigma_1 \log W + e \qquad (5.25)$$

where

$$\beta_0 = \sigma_1 \log \{g^{P} (1-c)^{-1}\} \text{ is a constant} \qquad (5.26)$$

σ_1 = estimated elasticity of substitution in a cross-sectional data

e = random error term, subject to standard assumptions.

Giving data on y (value added per man year) and W (average wage rate per worker), we may fit equation (5.25) by least squares techniques in order to estimate σ_1, β_0 and e.

Time Series Regression Model

The equation (5.25) is not fit to be used with time series data because there is no term in it to allow for technological progress through time. Therefore, Katz [58] solved the problem by assuming that the existing technology becomes more efficient through time, so as to shift the whole production upwards in a neutral way ($g = e^{\lambda t}$), where λ = the rate of neutral technical progress in efficiency improvement in terms of the ruling technology. Therefore, by replacing the value of g in equation (5.26) we obtain

$$\beta_1 = -\sigma \log \{1-c\} + \frac{p}{(1+p)} \lambda t$$

Then, the time series counterpart of equation (5.25) is

$$\log y = \beta_1 + \sigma_2 \log W + rt + e \qquad (5.27)$$

where $\beta_1 = -\sigma_2 \log (1-c)$ is a constant

σ_2 = a time-series estimate of the elasticity of substitution between labor and capital

$r = \lambda p/(1+p)$ or $\lambda = \frac{r}{(1-\sigma)}$ = the annual rate of technical change, and

e = the error term.

Regression (5.27) can be fitted to time series data. It could be estimated for the whole manufacturing sector covering the whole period or sub-periods in order to find out technological epochs in terms of technological progress. It also can be estimated for each industry separately in terms of neutral technological progress (λ), elasticity of substitution between capital and labor (σ) and distribution parameter (or capital intensity parameter - c). The actual data needed for the regression is y (output per man) and W (annual wage payments per worker).

CHAPTER VI.
TECHNOLOGY EPOCHS AND INTERINDUSTRY CORRELATION ANALYSIS

1. Technology Epochs

The method for measuring technological epochs is by applying stability analysis to discover periods of time within which the production functions remained stable. The basic assumption is that the ruling technology, embodied in existing production function, becomes more efficient through time in a neutral way, without affecting the ratio of the factors' marginal products. While this holds true we are still within a given technological epoch; even if the production function is shifting upwards each year in a neutral fashion - through a learning process on the margin. Once a structural break occurs we pass to a different technological epoch, i.e., the production function has changed in such a way that the ratio of the factors' marginal products have been changed for a given capital-labor ratio.[58:55; 54:114-118]

The operational procedure for isolating technological epochs is as follows: Suppose that the CES marginal productivity relation represented by equation (5.27) is fitted to data on value-added and wages-per-worker for a period of n observations. Another regression similarly specified is then run with n + m observations, to yield a second set of estimates. At this point we perform an F-test on the sum of squared residuals of the two regressions to test the hypothesis that the two regressions were generated by the same structure. If the hypothesis is true, that is,

it meets statistical acceptance level, then observations are added two at a time, and the regression is run again. This process is continued until the technological epochs are found.

Having roughly located the break, we may now gain more insight into the parameters of the CES production function changed from one technological epoch to the next and find out how much of the overall rate of growth of output is accounted for by the rate of technological advance in each of the two epochs at an aggregate level and subsequently at disaggregate level. We may watch that technological advance which increases or decreases the elasticity of substitution (σ), leads to the acceleration of the rate of productivity growth of one factor and to a slowing down of the rate of productivity growth of the other; that means it alters the marginal rate of substitution between factors, at each factor combination. This change of σ tells us that it stems from a technology which is new and non-neutral relative to the ruling one, because neutral technological advance is defined as not changing the substitution between factor inputs (σ). This non-neutral technological advance within an economy in which capital is growing more rapidly than labor means that a rise in the elasticity of substitution raises the marginal product of capital relative to that of labor; and we have a capital-using bias in change, but it does not tell us anything about the overall bias in technical change.

2. Sources of Output and Labor Productivity

The elasticity of substitution and rate of technological advance previously estimated at an industry level are related to the observed rates of growth of output and of labor productivity of each particular

industry in order to know the sources of growth and the major differences between the technological epochs previously uncovered.

Capital accumulation, factor substitution, technical progress, non-constant returns to scale and the rapid absorption of labor into the manufacturing sector have a significant impact upon the level of output and labor productivity. According to Katz,[58] employment tended to expand more rapidly in those sectors in which output also increased more rapidly because labor tended to move away from areas of extensive land cultivation and cattle breeding, and converged into regions in which industrial crops, manufacturing activities, and service industries expanded faster.

In the case that changes in output are correlated with the changes in employment, but not correlated with the changes in labor productivity, in an interindustry regression, the plausible answer would be that the changes in labor productivity are associated with changes in the capital-labor ratio under the condition that the whole technological advance is insignificant as a source of growth. An upward percentage change in the wage-rental ratio makes all of these industries, as well as each separately, to increase their capital-labor ratios in the same proportion. Hence, if uneven increases in the capital-labor ratio of different industries are the major source of uneven rates of labor productivity growth among industries, the Cobb-Douglas production function might become a misleading analytical tool.

The elasticity of substitution between factor inputs is affected by the changes in factor prices. The interindustry unevenness in labor productivity growth must arise due to the variations in the ease of substitution between factor inputs. Katz[58] indicates that industries with higher

elasticities of substitution would record large increases in their capital-labor ratios and therefore would achieve larger than average increases in their labor productivity. We can take the estimates of elasticity of substitution of industries and correlate their ranking according to elasticity of substitution with the ranking according to changes in output per man. We may obtain a Spearman rank order correlation between elasticity of substitution and labor productivity. Industries with high elasticity of substitution are more successful in substituting capital for labor, hence they recorded smaller increases in labor costs.

In sum, under the pressure of a rapid increase in the wage-rental ratio, the whole manufacturing sector moved towards greater capital intensity. Technologically, some industries found it easier to substitute capital for labor, and therefore those sectors became relatively more capital-intensive than average, and also became higher in labor productivity.

It was mentioned that increases in capital intensity might relate to increases in productivity. Capital intensity, however, cannot guarantee greater rates of technological advance because a greater than average increase in the capital-labor ratio does not necessarily constitute a particular advantage for making better technological progress. In a previous chapter it was indicated that the role played by technical advance and returns to scale at an aggregate level amount to 90% of the observed change in manufacturing output, but under the name of joint impact. In the following section of this chapter we will try to isolate the biased impact of the overall rate of technological advance.

3. A Modified CES Production Function

A number of factors such as education, technical improvements, and changes in quality of labor because of learning-by-doing have input-augmenting effects which can not be observed by conventional means. Therefore, the input-augmenting effects are suppressed and handled under the assumption of neutrality in technological advance. The second method developed by E. Denison [64] and Z. Griliches [65] and others considers the residual as the result of mismeasurement of the factor inputs. Conventional inputs of capital and labor are then corrected, and in addition, the impact of non-constant returns to scale is then made to account for the whole output (Katz [58]).

Changes in E_L and E_k over a period of time are considered as labor-augmenting and capital-augmenting, respectively, where $E_L L$ and $E_k K$ constitute, respectively, the inputs of labor and capital in efficiency units, L and K being defined as usual. A modified version of the CES production function has been used as a tool for studying the rate of factor-augmentation and biased factor savings (David and Klunkert [66]). The following is the modified model

$$Y = [(E_L L)^{-p} + (E_k K)^{-p}]^{-1/p} \qquad (6.1)$$

Equation (6.1) implies constant return to scale and elasticity of substitution $[\sigma = 1/(1+p)]$. It becomes

$$\frac{K}{L} = \left(\frac{wL}{rK}\right)^{\frac{\sigma}{1-\sigma}} \left(\frac{E_L}{E_k}\right) = \left(\frac{S_L}{S_k}\right)^{\frac{\sigma}{1-\sigma}} \left(\frac{E_L}{E_k}\right) \qquad (6.2)$$

where S_L and S_k denote the share of labor and capital, respectively. Assuming now that changes in E_L/E_k, the relative efficiency of labor,

take place at a constant geometric rate $(\lambda_L - \lambda_k)$, where λ_L and λ_k are the constant geometric rates of growth of the efficiency of labor and capital, respectively, then:

$$\frac{E_L}{E_k} = \frac{E_L(0)}{E_k(0)} \exp[(\lambda_L - \lambda_k)t] \qquad (6.3)$$

where $E_L(0)/E_k(0)$ represents the relative efficiency of labor at the base period. Thus,

$$\log \frac{K}{L} = \frac{E_L(0)}{E_k(0)} + \left(\frac{\sigma}{1-\sigma}\right) \log wL/rK + (\lambda_L - \lambda_k)\, t \qquad (6.4)$$

Equation (6.4) can be fitted by ordinary least squares to the data on capital, labor and relative factor shares in the manufacturing sector.

If the elasticity of substitution (σ) is significantly less than unity and the efficiency of labor $(\lambda_L - \lambda_k)$ grew at a rate greater than the rate of increase in the efficiency of capital, then the technological progress is not neutral, but biased in a labor-saving direction over the period to which we referred. We may compare the relative growth rate of capital with the growth rate of labor in different periods to see if there is any impact brought about by the inpouring of capital into the manufacturing sector by foreign direct investment or any other sources of capital formation.

4. Interindustry Correlation Analysis

The purpose of an interindustry correlation study is to investigate the relationship between changes in productivity and changes in other economic variables or to find out the sources of the output growth, especially to confirm the aggregate explanation of the growth pattern of the manufacturing sector in the various periods.

Now the relationship between changes in output and changes in multi-factor productivity is analyzed. A positive association is expected. If one assumes a neutral technological progress, i.e., if all industries are subject to the same potential economies of scale and technical progress, then output growth may be caused by differences in demand at different industries. There would be a positive relation between the increases in demand and the rate of output growth due to greater benefits from technological advance and economies of scale. In other words, those industries that have higher increase in demand and which expand production above average will enjoy an above average increase in their productive efficiency.

If one assumes, on the other hand, that the economy has a non-neutral technological advance, some industries stand to gain more potential technological progress and economies of scale because these industries have a more dynamic technology so as to have a higher productivity.

Actually, both assumptions are true. Different industries are subject to different benefits from technical advance and returns to scale. The pressures of demand are also different. Usually, industries with

higher than average income in elasticity of demand tend to have also higher than average economies of scale and technological progress.

According to Katz,[58] the autonomous part of an economy also can play an important role in the expansion of capacity. For example, a liberal foreign investment policy will have a vital impact on the expansion of plant capacity, reduce the labor share in GNP, and increase the rate of capital formation. All these effects will increase the productivity of labor, the rate of technical progress and economies of scale, and a faster growth of output. This sort of growth of output permits multiple effects in the production process, thus further leading to division of labor and to a higher labor productivity due to internal and external economies to be obtained from the expansion of output. This is also called the 'Verdoorn effect.'

As mentioned, foreign investment, technological progress and productivity growth are closely related. It is not just that the foreign private capital brings in modern technology to the specific industries in which it operates, but rather it has also brought in spillover effects, such as building up a satellite industry. Foreign direct investment also brings in business concentration and market imperfection problems. As Katz indicates, all in all this introduces a pattern of strong association between technological progress, productivity growth and the degree of business concentration.

Now, we are going to summarize the argument developed in the previous chapters and make an overall interpretation of the growth process in the manufacturing industry. Basic analytic tools are neo-classical production function and interindustry correlation analysis and emphasis will be put on foreign-capital and technological-advance oriented models of manufacturing growth.

Long-run growth in productivity derives from one or a combination of the following forces, capital formation, increasing returns to scale, ease of substitution between factor inputs (an increase in the elasticity of substitution between factor inputs when capital stock is increasing faster than that of labor) or technological advance (embodied in the factor inputs or disembodied in managerial, administrative and technical operation which might be influenced by new investment or by Verdoorn effects). First, the growth pattern in the Argentine manufacturing sector will be briefly examined.

Katz [58] analyzed the Argentine manufacturing sector and found out that in the earlier period (1946-1953) the Argentine manufacturing sector emerged from the war as a close enclave. Foreign capital and its associated technology had stopped flowing into the country, and domestic generation of modern technology was, at that stage, totally non-existent. The new vintage of investment stood no chance of acting as a vehicle for embodied technological progress. There were not any significant increases in the elasticity of substitution between factor inputs, nor were there increasing returns to scale to be gained with the expansion of output during this earlier period. Whatever growth there was in manufacturing output per capita is to be interpreted as derived from a movement along an existing production function, i.e., a movement from A to B along F_1 (K/L) in Figure 11.

In the next period (1954-1961), the empirical evidence indicates a different explanation for the output growth. Technical advance, operating alongside capital accumulation, was the major source of growth of manufacturing output per capita. A new F-curve of growth, F_2 (K/L), represents the new production function.

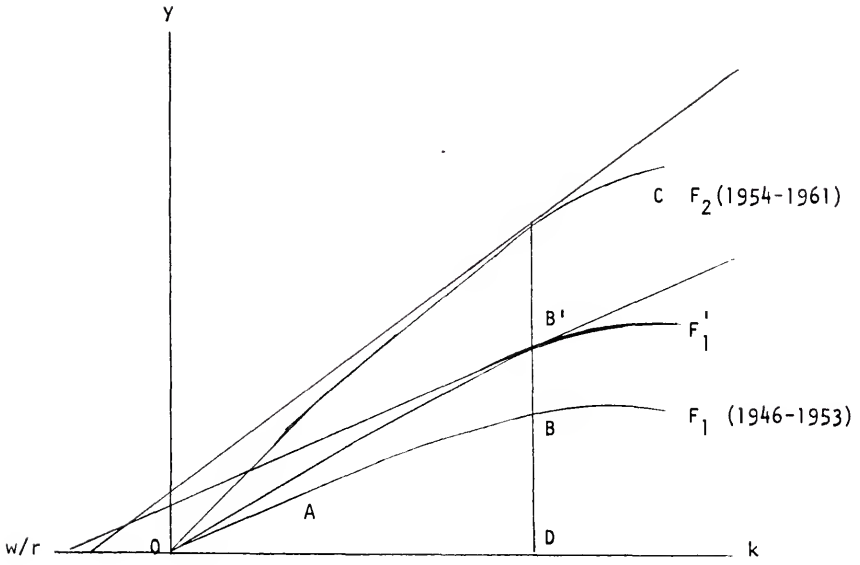

Figure 11: Nature of Output Growth

in this period, a non-neutral type of technical progress pushed the economy from B' to C, influenced by the government policies concerning foreign investment, tariff protection, industrial promotion, income policies and domestic policies which have tremendous impact on the reception of foreign private capital, elasticity of factor substitution and economies of scale.

The government policies, through the exemptions, accelerated depreciation and investment allowances, and reduced the cost of capital services. Factor prices were also changed to induce a further movement, along the new isoquants, in search for a higher capital intensity. Actually, not only were capital costs reduced in absolute terms, but also the relative cost with respect to the cost of employing labor

services. A diminishing capital cost induced domestic and foreign firms to investment and the relative factor proportion also changed in favoring the adoption of more productive processes of a higher capital intensity. In sum, it brought in two effects, relative factor prices effect and technology effect on the economy.

As mentioned, the relative factor prices effect induces capital intensity which affects the technology and always results in labor saving; while the technology effect brings about an acceleration of the rate of growth of overall factor efficiency and the possibility of increasing returns to scale which could be gained with the expansion of output. As to an increase in the elasticity of factor substitution, it can be labor-saving or capital-saving, depending upon whether capital is growing faster than labor or vice-versa. If capital is growing more rapidly in an economy than labor, a rise in the elasticity of substitution raises the marginal product of capital relative to that of labor, and we have capital-using (labor-saving) technological change. On the other hand, if labor is growing more rapidly than capital, we have a capital-saving (labor-using) bias in the technology. In the former case, a rise in the elasticity of substitution accompanying an increasing rate of capital growing faster than that of labor, results in output expansion. Contrarily, in the latter case, if the increasing rate of capital is slower than that of labor, the output will contract instead of expanding.

The above aggregate explanation of the growth pattern of the manufacturing sector will be subject to empirical confirmation in the following interindustry correlation analyses between manufacturing output, output per man, employment, elasticity of factor substitution,

technical progress, degree of concentration, foreign capital formation, gross domestic formation, and import and export. The relative effectiveness of government policies will also be scrutinized alongside output growth, technological progress and foreign capital formation in the various stages of the economy.

CHAPTER VII.
EMPIRICAL MEASUREMENT

1. Introduction

In this chapter, constant elasticity of substitution (CES) models developed in Chapters V and VI will be employed for estimating the elasticity of substitution between factor inputs and technological progress in the whole manufacturing industry and in each sub-industry of the manufacturing sector. This will be followed by correlation analyses and inter-industry comparisons. The theoretical framework established in the previous chapters will be used for the evaluation of empirical results.

The data sources are mainly from the *Census of Manufacturing* and *The Report on Industrial and Commercial Surveys* for the years from 1966 to 1975. Data were also obtained from various issues of the *Taiwan Statistical Data Book, Statistical Yearbook, National Income, Taiwan Industrial Production Statistics Monthly, Monthly Bulletin of Labor Statistics,* "Economic Indicators," *Monthly Statistics of Overseas Chinese and Foreign Investment and Technical Cooperation Projects, The Republic of China* and others.

These data were mainly provided by the Economic Planning Council, Executive Yuan, and Ministry of Economic Affairs, Republic of China. The author sincerely appreciates their support and efforts in collecting and air-mailing these huge materials for this research.

Basic data used for fitting CES production function models in order to estimate the rates of technological progress and elasticity of

substitution between factor inputs, capital and labor, are value added per man year and average yearly wages per worker at constant prices of 1971 for the manufacturing sector as a whole and for each sub-industry during the ten-year period 1966-1975.

A few points should be made regarding the adequacy of the data before the actual reports of the results. First, not all the sub-industries in the manufacturing sector are classified consistently during the ten-year period due to the reorganization of statistical units and different statistical methods employed by the units. The classification adopted here is in accordance with the classification of the 1971 *Industrial and Commercial Census of Taiwan and Fukien Area, Republic of China*. Table 1 shows the classification used in this research.

Table 1: Classification of Sub-Industries in the Manufacturing Sector

Code	Sub-Industries in the Manufacturing Sector
31	Food, Beverage and Tobacco Manufacturing Industries
32	Manufacture of Textiles, Wearing Apparel and Leather Products
33	Manufacture of Wood, Bamboo, Vine, Willow and Products
34	Paper and Paper Products, Manufacturing and Printing Industries
35	Manufacture of Chemicals, Crude Oil, Coal, Rubber and Plastic Products
36	Manufacture of Non-Metallic Mineral Products
37	Basic Metal Industries
38	Manufacture of Metal Products and Machinery Equipment
39	Manufacture of Miscellaneous Industrial Products

Second, consistently deflated price indexes for each sub-industry were non-existent. Wholesale price indexes, therefore, were used to deflate all value in money terms.

Third, no attempt has been made to adjust the variations in capacity utilization or the fluctuation in the level of economic activity during the recession years.

Fourth, comparatively consistent and reliable data can be obtained for this research for only ten years from 1966 to 1975. Limited observations in fitting CES production function models and regression analyses produce increasing bias. It does not, however, impair the usefulness of the results which still show the trend that could be used for policy guidelines. Besides, data limitations are a common phenomenon in almost all DCs. In accordance with these standards, the results are still valuable in terms of economic research.

2. Technological Progress and Elasticity of Substitution

(1) A Time Series Regression Model at Aggregate Estimates

Equation (5.27)

$$\log y = \log B_1 + \sigma_2 \log w + rt + e$$

has been fitted first at a macro-economic level for the manufacturing sector as a whole, and secondly, at each sub-industry level of the nine sub-industries. The former fit is to find out technological epochs in terms of technological progress. The second fit is to estimate each sub-industry's technological progress in terms of neutral technology (λ) and elasticity of substitution between factor inputs, capital, and labor (σ).

The actual data needed for this regression by least squares techniques are output per man year (y) and annual wage rate per man year (w) at constant prices of 1971.

Technological Epochs. In accordance with the theory of a structure break in the process of growth developed in Chapter VI, non-homogeneous years in terms of technological progress, from a statistical point of view, are not clear in this ten-year period. Following the procedure in isolating "technological epochs" yields the results shown in Table 2.

From Table 2, the observed value of the F-test for the period 1966-70 to 1966-72 is 13.64, a value which is greater than the theoretical value 9.55 at the 5% significance level. The structure break in this period is not clear. It is, however, quite clear in the next test for

Table 2: F-Test with Sum of Square Residuals to Isolate Technological Epochs in Each Sub-Period (1966-1975)

Periods	Sum of Squares Residuals	Degrees of Freedom	Value of F-Test Observed	Value of F-Test Theoretical	Level of Significance
1966-70	0.0238865^{-1}	$\frac{7-4}{2}$	13.64	9.55	5%
72	0.241047^{-1}			30.82	1%
1966-70	0.0238865^{-1}	$\frac{9-4}{2}$	68.32	5.79	5%
74	0.676656^{-1}			13.27	1%
1966-72	0.241047^{-1}	$\frac{9-4}{2}$	4.52	5.79	5%
74	0.676656^{-1}			13.27	1%

The value of $F = \frac{Q_3 / k}{Q_2/(m+n-2k)}$

Q_1 = the sum of square residuals of the regression for the first sub-period or the entire period.

Q_2 = that for the second sub-period or for the shorter period.

$Q_3 = Q_1 - Q_2$

k = the number of parameters estimated

m + n = the total number of observations in the regression for the entire period.

the period 1966-70 to 1966-74. The observed value of the F-test is 68.32, a value which is greater than either the theoretical value 5.79 at the 5% significance level or 13.27 at the 1% significance level. During the period 1966-72 to 1966-74, owing to the oil crisis in 1974, the observed value of the F-test falls behind the theoretical value again at both significance levels.

Checking the growth rates of economic indicators of the economy, one is convinced that if there were not such a severe recession, Taiwan's economy might have dashed up to a new peak in the second half of the ten-year period; because Taiwan is an island economy, it depends heavily upon foreign trade for growth and survival, e.g., in 1975, Taiwan's export as a percentage of GDP is as high as 40.4%. Import percentage of GDP in the same year is also high, up to 44.1%.* Overall economic structure in Taiwan is shown in Table 3.

As indicated, there is some evidence that a structural break occurred in the period 1971-72. We may proceed with another F-test to see whether the population generated by the observations for the first half of the ten-year period was homogeneous with the population generated by the observations for the second half of the ten-year period, because the structure break, roughly located, is about in the middle of the ten-year period of our investigation. So the ten-year period may be evenly divided into two five-year sub-periods for the convenience of investigation.

Following the same test procedure outlined above, the overall F-test for the whole period was run with the results presented in Table 4.

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* "Economic Indicators, Taiwan, Republic of China," Ministry of Economic Affairs, Republic of China.

Table 3 Economic Structure

Item	Unit	At Current Prices			
		1952	1973	1974	1975
As Percentage of GDP					
A. Gross Savings	%	9.2	33.1	30.1	25.3
B. Public and Private Consumption	%	90.8	67.0	69.8	74.6
C. Gross Capital Formation	%	15.3	27.4	38.3	28.8
D. Imports of Goods and Services	%	14.1	43.5	53.5	44.1
E. Exports of Goods and Services	%	8.0	49.1	45.4	40.7
As Percentage of GDP					
A. Industrial Output	%	17.9	40.1	38.4	36.3
B. Agricultural Output	%	35.7	15.1	15.7	16.3
C. Service and Others	%	46.4	44.8	45.9	47.4

Note: Gross savings exclude current transfers from the rest of the world

Source: "Economic Indicators, Taiwan, Republic of China," Ministry of Economic Affairs, Republic of China, June, 1976.

Table 4: F-Test with Sum of Squares Residuals to Locate Technological Epochs in the Whole Period (1966-75)

Periods	Sum of Squares Residuals	Degrees of Freedom	Value of F-Test Observed	Value of F-Test Theoretical	Significance Level
1966-70	0.0023886	$\frac{10-4}{2}$	6.29	5.14	5%
1971-75	0.035845				
1966-75	0.119893			10.92	1%

The evidence provided in Table 4 is that no non-homogeneous structure break occurred in these two sub-periods, because the observed value of the F-test of 6.29 is less than the theoretical value 5.14 at the 5% significance level and 10.92 at the 1% significance level.

A third test was done to check whether the parameters of the CES production function changed from the first sub-period 1966-70 to the second sub-period 1971-75. From Table 5, the elasticity of substitution between factor inputs, capital and labor (σ) and technological progress (λ) in the second half of the ten-year period has increased. The coefficients of determination are normal, with the rates of technological progress statistically significant at the 5% to 10% levels.

Table 5: Elasticity of Substitution and Technological Progress in the Whole Period (1966-75)

Periods	Elasticity of Substitution (σ)	Rate of Technological Progress (λ)	R^2
1966-70	0.09 (E)	0.10 (B)	0.97
1971-75	0.72 (E)	0.43 (C)	0.88
1966-75	-0.05 (E)	0.11 (B)	0.89

Significance Levels: B = 5%; C = 10%; E = Non-significance

Labor Productivity Growth Pattern. Figure 12 is based upon the actual data on value added per man year for the ten-year period and two CES production functions, one for the first half of the ten-year period 1966-70, another for the second half of the ten-year period 1971-75.

From Figure 12, there is a clear picture of Taiwan's labor productivity growth which is the function of technological progress during the ten-year period. This reinforced the conviction that there was no clear-cut, non-homogeneous structural break which occurred in this ten-year period. As indicated before, there might be one in the period of 1971-72.

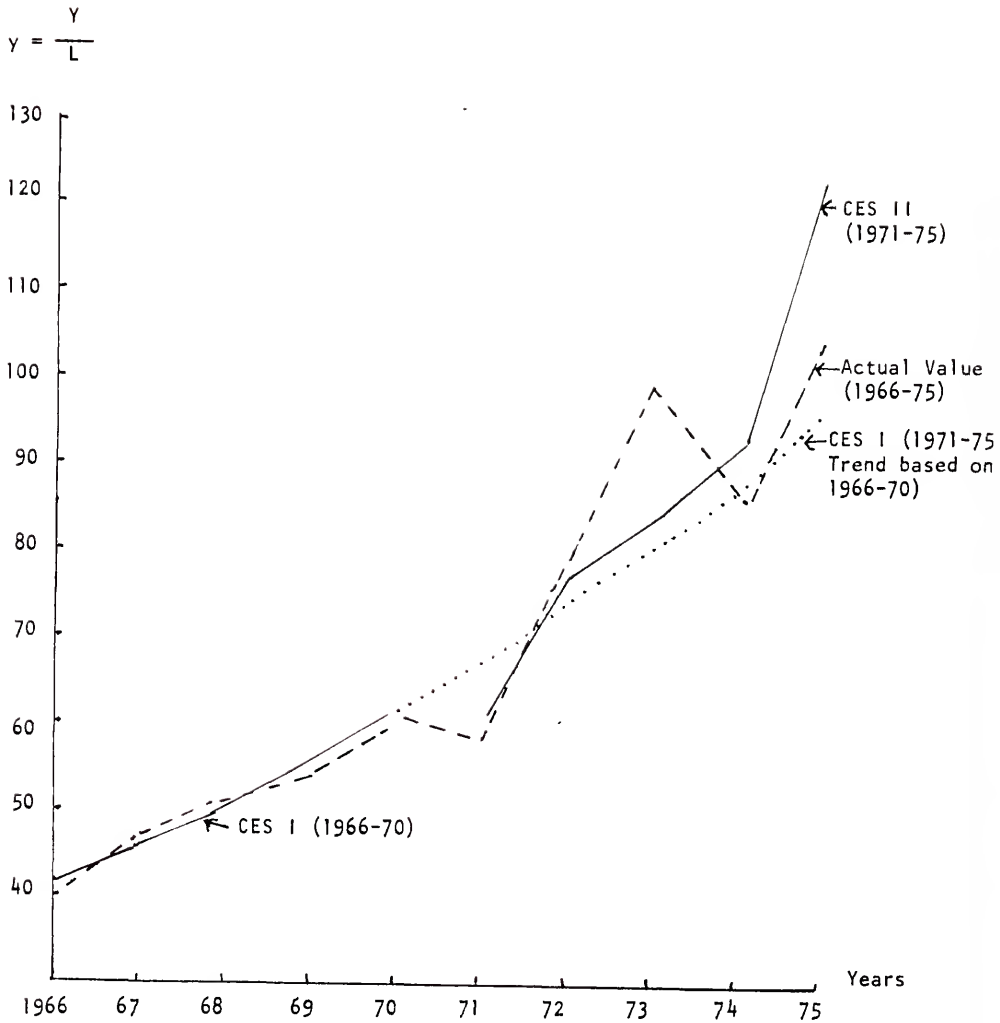

Figure 12. Labor Productivity in Manufacturing Industry 1966-75

CES I: $\log y = -157.488 + 0.0879523\ w + 0.08510\ t \quad R^2 = 0.97$
CES II: $\log y = -234.743 + 0.717008\ w + 0.121068\ t \quad R^2 = 0.88$

From the map, it is clearly indicated that from 1971 to 1972, Taiwan's labor productivity, which is technologically determined, climbed up to a new plateau. Of course, the magnitude of growth was mild and did not constitute a structural break because it grew at a normal pace. If there had been no world recession in 1974 which reduced the momentum, the technological progress might have driven the economy to a new frontier. If we take a closer look at the map, it clearly manifests a new trend beginning in 1975. After the recession, Taiwan's economy immediately dashed up again. Hopefully, it would be a starting point for a new plateau, and a new non-homogeneous structural break would be begun.

(2) A Time Series Regression Model at Disaggregate Estimates

Equation (5.27) has been used at a disaggregated, sub-industry level for estimating the rates of technological progress and elasticities of substitution between factor inputs of each sub-industry.

Having previously indicated that a quasi-structural break might have occurred in 1971-72, equation (5.27) is now applied to each sub-industry to estimate their technological progress and elasticity of substitution between factor inputs in the two sub-periods 1966-70, 1971-75, and in the whole ten-year period as well.

Tables 6, 7, and 8 are the results of the fits with data on value added per man year and annual wage rate per worker at constant prices of 1971 as the base year.

In the first fit for the whole ten-year period 1966-75 (Table 6), the rates of technological progress and elasticity of substitution between factor inputs for the whole manufacturing sector and for each sub-industry were statistically tested and it was found that more than half of them are significantly different from zero at the 1% to 20% levels. It was also found that the rates of technological progress and elasticity of substitution between factor inputs for capital-intensive sub-industries were also significantly different from zero at the 1% to 20% levels, e.g., in the rates of technological progress, foodstuffs (significantly different from zero at the 5% level), wood and bamboo (at the 1% level), paper and printing (at the 20% level), chemicals (at the 20% level), and metal and machinery (at the 1% level). On the other hand, the rates of technological progress

Table 6: Time Series Estimates at Disaggregate Level (1966-75)

Sub-Indistries	Elasticity of Substitution		Rates of Technological Progress		R^2
Foodstuffs	-0.61	(E)	0.15	(B)	0.87
Textiles and Leather	0.35	(E)	0.13	(E)	0.82
Wood and Bamboo	-0.99	(D)	0.11	(A)	0.79
Paper and Printing	0.50	(D)	0.11	(D)	0.92
Chemicals	0.76	(D)	0.21	(D)	0.82
Non-Metallic	0.78	(C)	-0.13	(E)	0.61
Basic Metal	1.25	(E)	-0.13	(E)	0.45
Metal and Machinery	0.23	(E)	0.11	(A)	0.94
Miscellaneous	1.12	(C)	-0.15	(E)	0.83
Manufacturing Industry	-0.05	(E)	0.11	(B)	0.89

Significance levels are: A = 1%; B = 5%; C = 10%; D = 20%; and E = non-significance

and elasticity of substitution between factor inputs for the labor-intensive industries such as textiles and leather, non-metallic, basic metal and miscellaneous sub-industries were not significantly different from zero.

The logical explanation is that because the rates of technological progress and elasticity of substitution between factor inputs were growing more steadily for the capital-intensive sub-industries which were in a better competitive position and less disturbed by the world recession caused by the oil crisis in 1974, their data are more consistent; so the significance levels of the statistical tests are also higher. On the opposite side, labor-intensive sub-industries were in a poor competitive position compared with capital-intensive sub-industries. These labor-intensive sub-industries were most disturbed by the world recession, some of them even being driven out of the markets, so their data are not consistent due to severe fluctuations caused by the oil crisis in 1974. The rate of technological progress for the whole manufacturing industry for the ten-year period was significantly different from zero at 5%, which indicates that the technological progress for the whole manufacturing sector during the ten-year period was growing steadily at an average of 11%, and this progress was statistically tested and showed that the figure is reliable at the 5% significance level.

In the second fit for the first half of the ten-year period 1966-70 (Table 7) and in the third fit for the second half of the ten-year period 1971-75 (Table 8), the same results were obtained. Comparing the results of the two sub-periods 1966-70 and 1971-75, we found that the sub-industries with increasing rates of technological progress in the second sub-period 1971-75 compared with that in the first sub-period 1966-70 were

Table 7: Time Service Estimates at Disaggregate Level (1966-70)

Sub-Industries	Elasticity of Substitution		Rate of Technological Progress		R^2
Foodstuffs	1.68	(E)	0.01	(E)	0.74
Textiles and Leather	0.54	(D)	0.14	(D)	0.98
Wood and Bamboo	0.63	(E)	0.15	(E)	0.57
Paper and Printing	3.14	(C)	0.11	(D)	0.83
Chemicals	1.16	(C)	-0.05	(E)	0.71
Non-Metallic	-1.68	(E)	0.05	(E)	0.13
Basic Metal	2.58	(E)	-0.06	(E)	0.62
Metal and Machinery	-0.62	(A)	0.15	(A)	0.99
Miscellaneous	0.15	(D)	0.33	(A)	0.99
Manufacturing Industry	0.09	(E)	0.10	(B)	0.97

Significance levels are: A = 1%; B = 5%; C = 10%; D = 20%; and E = non-significance

Table 8: Time Service Estimates at Disaggregate Level (1971-75)

Sub-Industries	Elasticity of Substitution		Rate of Technological Progress		R^2
Foodstuffs	0.47	(D)	0.69	(A)	0.99
Textiles and Leather	-0.46	(E)	0.06	(E)	0.24
Wood and Bamboo	0.00	(E)	-0.16	(E)	0.40
Paper and Printing	0.41	(C)	0.13	(A)	0.97
Chemicals	0.73	(E)	0.52	(C)	0.86
Non-Metallic	1.38	(B)	0.02	(E)	0.90
Basic Metal	1.38	(E)	-0.39	(E)	0.58
Metal and Machinery	0.22	(E)	0.08	(D)	0.72
Miscellaneous	1.45	(B)	0.00	(E)	0.95
Manufacturing Industry	0.72	(E)	0.43	(C)	0.88

Significance levels are: A = 1%; B = 5%; C = 10%; D = 20%; and E = non-significance

generally capital-intensive sub-industries. Since their data are more consistent, as explained above, their significance levels are also higher, e.g., foodstuffs (at the 1% level), paper and printing (at the 1% level), and chemicals (at the 10% level).

Concerning the rates of technological progress and elasticity of substitution between factor inputs for the labor-intensive industries, such as textiles and printing, non-metallic, basic metal and miscellaneous sub-industries, they are not statistically significantly different from zero for the reason explained above. As to the rates of technological progress for the whole manufacturing sector in the two sub-periods, both are significantly different from zero at the 10% level. This also indicates that the technological progress grew steadily from an average of 10% in the first half period to an average of 43% in the second half period, and these figures were statistically tested and showed that they are reliable at the 5% significance level in the first half period and at the 10% significance level in the second half period.

The above explanation is based on the general trend. The exact behavior of each sub-industry still depends upon the characteristics of each sub-industry and the environment the sub-industry was in. Though the results were somewhat restrained by limited observations, as mentioned, the trend is still clearly shown.

The explanatory power of the regression equation (5.27) seems quite high. The results of the regression revealed that the role played in the regression by the rates of technological progress and elasticity of substitution between capital and labor in the two sub-periods is not clearly different between the two sub-periods. Though the rates of technological progress and elasticity of substitution were slightly higher in the second half of the ten-year period 1971-75 than that in the first half of the ten-year period 1966-70 at aggregate level, they were not clear at the disaggregate level.

For example, the rates of technological progress in the second half of the ten-year period compared with that in the first half of the ten-year period, for seven out of nine sub-industries in the second half of the ten-year period, are lower due to the impact of the oil crisis. The average rate of technological progress in the second period, however, was still slightly higher than in the first period. The situation on elasticity of substitution between capital and labor was about the same.

The above results reveal the real situation of Taiwan's economy. In aggregate level, Taiwan's economy was advancing toward a new plateau; in disaggregate level, however, the behavioral patterns of each sub-industry in reaction to the world-wide recession were diversified because, as mentioned earlier, each industry has its specific characteristics and capabilities in meeting the challenge of the most severe recession. As also mentioned before, since Taiwan's economy is an island economy, it depends heavily upon foreign trade.

Now, let us examine some of these behavioral patterns. The rates of technological progress in six out of nine sub-industries decreased.

The typical ones are textiles and leather, wood and bamboo, non-metal and basic metal sub-industries. Most of them are labor-intensive sub-industries. They were in weak positions to compete with capital-intensive industries because the world was in recession. Almost all developed countries with purchasing power were tightening their belts to curtail imports in order to balance their budgets. Under this world-wide contraction, only the products with good quality can stand in the markets. The labor-intensive industries usually produce products of lesser quality, so they are the hardest hit by the world recession. This is also the reason their technology decreased. Some of them were even driven out of the market. This is also the reason the growth rate of Taiwan's employment is minus (-0.11) in 1974. Fortunately, the world recession ended quickly with almost all economic indicators immediately jumping up to a new peak in 1975 or 1976.

By comparing these real facts with the results produced by the time series model of the production function, the data are convincing that the time series model had a good fit and produced consistent results which can be used to explain the real phenomena in Taiwan's economy as well as in comparable economies of the world.

In addition to the weak competitive position in the world market, the labor-intensive industries have many other weaknesses, e.g., as Katz indicated, these industries were particularly affected because the skills, technological constraints, and capital requirements were then rather low, and did not constitute obstacles for new entries.[58]

On the reverse side, some capital-intensive industries, such as chemicals and paper and printing experienced increasing rates of technological progress even under such a severe world recession. The

growth rates of labor productivity in these capital-intensive industries were also high among the nine sub-industries.

Taiwan's economy is characterized by the above-mentioned phenomena. Manufacturing production occupied 84% of the nation's industrial production, and the production of three sub-industries, such as textile and leather, chemicals and metal-machinery-electrical, in turn occupied 71% of the manufacturing production. Taiwan's economy advancing toward capital intensive industry is a recent phenomenon. During the oil crisis, Taiwan's economy was basically labor-intensive, so it received a severe setback. Industrial weights for the index of industrial production are shown in Table 9.

Table 9: Industry Weights for the Index of Industrial Production

Industry	Relative Weights			
	1954	1961	1966	1971
General	1000.00	1000.00	1000.00	1000.00
Mining	101.73	81.29	68.89	34.66
Manufacturing	722.47	821.42	802.45	840.71
Foodstuffs	216.39	213.91	140.17	91.85
Textiles and Leather	184.23	128.35	128.42	207.66
Wood and Bamboo	36.40	30.26	23.97	32.92
Paper and Printing	33.62	55.81	38.05	33.34
Chemicals	108.22	111.89	138.96	222.81
Non-Metallic	59.08	117.45	83.67	35.62
Basic Metal	29.88	30.08	53.81	34.41
Metal and Machinery	55.67	24.52	111.71	173.47
Miscellaneous	14.92	5.13	4.05	8.63
Electricity, Gas and Water	115.41	86.62	97.95	87.97
Construction	10.39	9.67	30.71	36.66

Sources: "Statistical Yearbook of the Republic of China," Directorate-General of Budget, Accounting and Statistics, Executive Yuan, The Republic of China.

3. Estimating Input-Augmenting Effects

In order to estimate the input-augmenting effect during the ten-year period, a modified CES production function model developed in Chapter VI has been used. Equation (6.4) has been fitted by ordinary least squares techniques to aggregate data on the value of assets in operation, labor, and relative factor shares in the manufacturing sector for the ten-year period 1966-75.

The value of assets in operation used in the equation instead of capital registered in the manufacturing sector was advised by the Economic Planning Council, Executive Yuan, Republic of China due to the fact that capital registered may not be the capital actually used in operation. The regression results are shown in Table 10.

The evidence shown in Table 10 indicates that Taiwan's technological progress in manufacturing over the ten-year period was not neutral. The efficiency of labor grew at a rate 11.48% higher than the rate of increase in the efficiency of capital; technological progress has been biased in a labor-saving direction over the ten-year period.

This finding is consistent with overall economic behavior in Taiwan, e.g., Taiwan's wage rate has climbed steadily over the ten year period, especially over the second half of the ten-year period. In 1972, the bias over labor-saving reached 39.32%, followed by 37.18% in 1973. Due to the recession in 1974, it began to drop to 23.11%. This phenomenon is entirely consistent with the "technological epochs" found in the previous section.

Table 10: Results of Input Augmenting Effect (1966-75)

Period	σ	$\lambda_L - \lambda_K$	R^2
1966-70	-0.37 (0.12)	8.35%	0.97
71	1.23 (0.46)	27.23%	0.99
72	1.22 (0.45)	39.32%	0.98
73	1.21 (0.41)	37.18%	0.98
74	1.22 (0.43)	23.11%	0.97
75	1.24 (0.44)	11.48%	0.96

Standard Deviations are given in brackets below the regression coefficients

The bias toward labor-saving means higher labor productivity and capital intensity because of capital-using and technological change. In Taiwan, capital grew much faster than labor; labor productivity, and capital intensity both soared up, so output also rose sharply.

Increasing labor productivity and capital intensity were caused by several factors. First, foreign direct investment made two contributions, one through capital formation which brought in money capital and human capital; another was through labor-intensive investment that made Taiwan's abundant factor endowment, labor, fully utilized. Second, the severe recession introduced by the oil crisis in 1974 forced most enterprises in Taiwan to lay off employees which also pushed up labor productivity and capital intensity because the fixed assets in operation were difficult to cut in a short time period. Third, after the recession, the laid-off employees who had already gone back to their farm land were reluctant to go back to their factories. Thus the labor market was very tight and wage rates soared upward. In order to save labor costs, entrepreneurs were forced to employ more capital than labor. This is the fourth cause of Taiwan's increasing labor productivity and capital intensity. This topic will be taken up later on.

4. Correlation Analysis

In this part of the chapter, overall correlation analysis will be presented to cover three major topics. First, the relationship between changes in productivity and changes in other economic variables, such as output, capital, employment, capital intensity, wage rate and technological progress. Second, the relationship between changes in foreign investment and changes in other economic variables, such as domestic fixed capital formation, savings, GNP, per capita income, production manufacturing, and technological progress. Third, comparison of average changes in the growth rates of major economic indicators between the two sub-periods.

Table II shows the growth rate correlation between productivity and other economic variables. They are statistically significant. The correlation coefficient between output and productivity is 0.71. This is the so called "Verdoorn effect." According to Verdoorn, the expansion of output permits the introduction of new processes, new modes of production and new technology. This will lead to a further division of labor and open a new frontier of expansion and lead to higher productivity because there are internal and external economies to be gained with the expansion of output. This is also exemplified by the learning-by-doing hypothesis.

Productivity is also correlated with capital employed. Here we use value of assets in operation. As mentioned earlier these data are superior to capital registered because the latter may not be the capital actually used. The correlation coefficient between productivity and cap-

Table 11: Growth Rate Correlation, Manufacturing Industry, 1966-75 (Value of r)

	Value of Output	Value of Production Per Head	Value of Assets in Production	Employment	Capital Per Head	Wage Rate	Technological Progress
Value of Output	1.00	0.71	0.79	0.64	0.43	0.11	0.65
Value of Production Per Head		1.00	0.91	0.31	0.84	0.30	0.31
Value of Assets in Production			1:00	0.59	0.85	0.17	0.23
Employment				1.00	0.11	-0.22	0.30
Capital Per Head					1.00	0.51	0.03
Wage Rate						1.00	0.07
Technological Progress							1.00

ital employed is 0.91. As more capital is employed, capital intensity rises. There is a high correlation of 0.84 between productivity and capital intensity.

Labor productivity should also be highly correlated with wage rate because the higher the wage rate, the higher the cost of production. This will force the entrepreneur to utilize more capital and less labor, so as to increase productivity. Of course, one prior condition that must be met before productivity will go up is that the growth rate of capital must increase faster than that of labor. By checking the overall growth rates of economic indicators in Taiwan, it was found that the growth rate of capital in the ten-year period was 19 percent, which was much higher than the 8 percent growth of labor during the same period of time. The correlation coefficient is 0.30 which is low due to the difficulties in adjustment of wages during the ten-year period and the chaotic situation caused by the oil crisis, e.g., the growth rate of wages during the recession is -0.05 for both 1973 and 1974; but in 1975 the growth rate of wages suddenly jumped to 0.24. Though the precision of the results is affected by this kind of abnormal behavior, the overall tendency is still clearly shown.

The growth rate of labor should correlate more with output instead of productivity. The correlations of the growth rates of labor with the growth rates of output and productivity are 0.64 and 0.31 respectively. Because the higher the employment, the more people participated in the production line, so the higher the output. As regards productivity, this should not push up productivity too much, so the correlation coefficient is a low 0.31, and it should be even lower.

In addition to capital formation and capital intensity contributions to the growth of productivity, there are some other factors, such as tech-

nological progress, elasticity of substitution between factor inputs and foreign investment. Here the correlation coefficient between the growth rate of productivity and that of technological progress is 0.31, but this does not mean that they are not correlated, because the rates of technological progress used for fitting the correlation equations are not adequate.

The basic difficulty in calculating cross section technological progress is limitations of data. The regional data classified into sub-industries are non-existent in Taiwan. It was, therefore, necessary to use the data on nine sub-industries for each year as observations to calculate each year's technological progress which was, in turn, used to correlate with other economic variables. The results of correlation are not satisfactory.

As indicated, the low correlation coefficient should not be interpreted as poor correlation between productivity and technological progress. We can resort to the comparison of average change in growth rates of major economic indicators between the two sub-periods in the ten-year period to trace their relationship. We will take up this point shortly.

Now, let us examine the effect of elasticity of substitution. As mentioned earlier, capital intensity can make contributions toward productivity, but cannot guarantee higher productivity because it depends upon the rate of elasticity of substitution between factor inputs. If the rate of elasticity of substitution $\sigma > 1$, the price of labor goes up, and the capital share of output will increase. If $\sigma < 1$, the reverse situation, the capital share of output will go down.

Table 12 shows the growth rate correlation between foreign investment and other economic variables. The correlation coefficient between foreign investment and domestic fixed capital formation is 0.63. As

Table 12: Growth Rate Correlation of Major Economic Indicators, 1966-76, (Value of r)

	Direct Foreign Investment	Domestic Fixed Capital Formation	Savings as % of NI & GNP	Gross National Product	Per Capita Income	Domestic Product Mfrg.	Technological Progress
Direct Foreign Investment	1.00	0.63	0.60	0.68	0.64	0.64	0.09
Domestic Fixed Capital Formation		1.00	0.43	0.54	0.93	0.86	0.45
Savings as % of NI & GNP			1.00	0.91	0.93	0.86	0.40
Gross National Product				1.00	0.98	0.91	0.51
Per Capita Income					1.00	0.84	0.59
Domestic Product Mfrg.						1.00	0.37
Technological Progress							1.00

indicated earlier, economic growth is a function of productivity which is technology determined. Productivity is also a function of capital formation. Based on this chain correlation, we know foreign investment contributes to economic development. Table 12 shows also that the growth rate of foreign investment is correlated with savings, GNP, per capita income, manufacturing production, and technological progress. The correlation coefficients are 0.60, 0.68, 0.64, 0.64 and 0.09 respectively.

By examining Table 11 and Table 12 at the same time it can be seen that these economic variables are interrelated in a delicate fashion. Especially, it proves foreign investment contributes more to total production than to productivity through capital formation.

Now, let us take up a third topic, the comparison of average change of growth rates in major economic indicators between the two sub-periods of the ten-year period (Table 13). Here we can see that when the growth rate of capital intensity, defined as capital per worker, goes up, the productivity, defined as output per worker, goes up and is accompanied by increasing rate of technological progress and elasticity of substitution between factor inputs. Here the rates of technological progress and elasticity of substitution were calculated by fitting CES production function models with time series data on the manufacturing indudtry as a whole in the two sub-periods 1966-70 and 1971-75 respectively. So the data are more reliable and the results are more consistent.

The increasing rate of technological progress and elasticity of substitution between factor inputs is vitally important because capital intensity contributes to productivity and must be under an increasing rate of technological progress and appropriate elasticity of substitution between factor inputs, labor and capital, so that the increasing capital can be substituted for labor. Another feature is that it is accompanied

by decreasing employment which helps by pushing up capital intensity, especially during the recession period.

It must be noted that here the increased capital intensity was caused by three factors: One was the increasing wage rate, another was the decreasing employment rate, and the last was foreign investment which contributed to capital formation.

Usually, increasing capital intensity is caused by an increasing wage rate, but in the case of Taiwan's economy during the oil crisis, it was largely caused by the laying-off of employees. Of course, it was a temporary phenomenon. As mentioned before, Taiwan's economy in the manufacturing sector was one of labor-intensive industries. Taiwan's abundant productive factor, labor, was fully utilized to the point where the wage rate began to climb. So we conclude that the increasing capital intensity from 0.08% in the first half of the ten-year period 1966-70 to 0.12% in the second half of the ten-year period 1971-75 was basically caused by the combined effects, increasing wage rate, laying off of employees during the oil crisis, and foreign direct investment.

Table 13 shows that increasing capital intensity usually accompanies increasing labor productivity which is technology determined, though capital intensity can not guarantee higher technological progress. Here, when the growth rate of capital intensity (K/L) went up from 0.08% in the first half of the ten-year period to 0.12% in the second half of the ten-year period, technological progress went up from 0.10% to 0.43% while labor productivity also went up from 0.06% to 0.15% in the same two sub-periods.

Of course, the fact that the elasticity of substitution went up from 0.09% in the first sub-period to 0.72% in the second is also important because it tells us that the productive factor inputs, capital and labor, were freely substituted for each other. This was a very impor-

Table 13: Comparison of Average Change of Major Economic Indicators Between Two Sub-Periods

	Value of Output Per Head	Capital Per Head	Employment	Elasticity	Technological Progress
1966-70	0.06	0.08	0.16	0.09	0.10
1971-75	0.15	0.12	-0.01	0.72	0.43

tant element for the economy to use efficiently its factor endowment so as to cause the output expansion. Though the growth rate of output fell behind other variables, it was basically caused by the world recession, which introduced economic disorder throughout the world, especially the export-oriented economy of Taiwan where many economic variables behaved abnormally.

In Table 12, foreign investment is correlated with domestic fixed capital formation. The correlation coefficient is 0.63. In Table 11, productivity is correlated with the value of assets in operation. Therefore, foreign investment made contributions toward productivity through capital formation. In Table 13, as technological progress went up from 0.10 in the first half of the ten-year period, to 0.43 in the second half of the ten-year period, productivity also increased from 0.05 to 0.15 in the same periods.

5. Overall Evaluation

There are two basic types of theories concerning contributions made by foreign direct investment towards developing countries. The optimist takes the view that foreign investment is a carrier of technology. It brings into the developing countries money capital and human capital which are important for their economic development. The pessimistic view is that foreign investment is not beneficial and may even be harmful towards developing countries.

Salehkhou's [6] viewpoint towards foreign investment by multinational corporations as exploitation has been introduced. He condemned it. Now, we may review a case study made by Cohen [67:119] with specific reference to Taiwan. Based on the factual data on Taiwan, he indicated, "I conclude from all these tables and arguments that, in a comparison of foreign investment with an expansion of local firms, neither the direct nor the indirect economic benefits of this type of foreign investment are very great, if they exist at all. By most indices foreign firms resemble local firms, and by a few indices foreign firms are less beneficial to the local economy than the local firms. One might have hoped for a more dramatic conclusion."

Although the above viewpoint and theories conflict it seems both have some merit. From a pessimistic point of view, the behavioral pattern demonstrated by foreign firms in Taiwan is not too far away from Cohen's [67] remarks. From the optimistic point of view, Taiwan's economic boom is a fact. The per capita income climbed up from a U. S. equivalent of $52 in

1952 to a U. S. equivalent of $700 in 1976. The logical interpretation is that foreign firms that invested in Taiwan were largely labor intensive and Taiwan had abundant and cheap labor and thus the productive factor endowment was fully exploited, definitely contributing to the economy. There are some other contributions made by foreign investment, the most salient one being capital formation which in turn contributed to the growth in capital intensity. Capital intensity usually brought in technology through import of both capital goods and human capital.

In conclusion, economic growth is a function of labor productivity which is technology determined. Technological progress in turn is a function of capital formation contributed by foreign direct investment. Of course, this is only a general connection. They are interrelated in a delicate fashion. It must be interpreted with care. The specific environment, internal and external, must be taken into consideration also. Especially during the ten-year period under our investigation, a severe recession caused by the oil crisis has made every economic indicator behave somewhat abnormally. When we make any interpretation, we must keep an eye on the implications of the world-wide oil crisis.

The summary note made by James Riedel[68:505-28] in his case study of Taiwan is quoted to reinforce the findings in this research. Riedel indicates that foreign firms do not tend to be more capital-intensive and even employed more labor per unit capital. The major motive for foreign firms to invest in Taiwan is cheap labor. The main achievement of foreign investment is the demonstration effect. Riedel said, "The success of foreign firms in the export markets may have strong horizontal demonstration effects on domestic entrepreneurs. . . . It is evident from the experience of these countries which, like Taiwan, have

achieved success with outward-looking industrialization that direct foreign investment can make important contributions in assisting the developing countries to develop and exploit their comparative advantages."

This summary note is consistent with the findings in this research. Foreign investment made contributions in helping Taiwan fully utilize its factor endowment, labor, allowing the abundant factor inputs to join the productive force. Second, it brought in human capital with managerial techniques. Riedel terms it the demonstration effect. Third, it brought in money capital which pushed up capital intensity.

Baca [63:147] indicates, "There is statistical evidence that FDI interacts with high capital intensity to generate faster growth rates of total production, but does not contribute to an improved total factor productivity." Actually, it might contribute indirectly through capital formation.

CHAPTER VIII.
IMPLICATION AND CONCLUSIONS

A theoretical framework has been established for reviewing and evaluating the nature and mechanisms of technological transfer from ACs to DCs. An interface model of international technology transfer has also been built up for the reader to have a clear picture of technological transfer process, its elements, boundaries, interrelationships, mechanisms, and overall functioning in the process.

Relevant literature has been broadly reviewed in two key areas, non-economic and economic aspects of technological transfer. In the non-economic aspect, we defined technology as a total culture change. Attention has been given to conceptual models and human factors. Emphasis was on an interface model of ITT and the learning-by-doing hypothesis. In building up the interface model, modern concepts of management information systems and invention-innovation-diffusion process were used. The learning-by-doing hypothesis was empirically tested along with the "Verdoorn effect," and was found highly correlated with it.

The five problems listed on page two have been fully dealt with. The research findings are as follows:

1. During the ten-year period 1966-1975, Taiwan's rates of technological progress and elasticity of substitution between factor inputs for the whole manufacturing sector and for each sub-industry were growing steadily even under world recession. The more capital intensive the industry, the more significantly different from zero was the statistical test of its rates of technological progress and elasticity of substitution. Because capital-intensive industries were less disturbed by the world recession, their data were more consistent.

2. The correlation coefficients between technological progress and other economic indicators such as output, labor productivity, capital (value of assets in operation), employment, capital intensity, and wage rate are 0.65, 0.31, 0.23, 0.30, 0.03, and 0.07 respectively. As mentioned, due to data limitations, the correlations were not as great as expected. It was, however, clearly shown that technological progress was closely correlated with output and labor productivity.

3. In the ten-year period 1966-1975, there were no major structure breaks in terms of technological progress. A quasi-structure break was found around 1971-1972. The momentum of technological progress was dragged down by the world recession due to the special characteristics of Taiwan's economy which is vulnerable to the fluctuations of foreign trade. The overall technological progress still advanced steadily, though mildly, at the aggregate level. At the disaggregate level, progress entirely matched with the characteristics of the subindustry concerned. From the research findings, the labor-intensive industries were in a weak position to compete with capital-intensive industries, especially during world recession. The present policy pursued by the Chinese government in Taiwan toward development of capital intensive heavy industry is correct. As to input-augmenting effect, labor efficiency was much higher than that of capital during the ten-year period. The rate of labor efficiency was highest in 1972 and also dragged down by the world recession in 1974. The research findings are entirely consistent and interrelated. It definitely enhances our confidence in the results. It is not only consistent with the findings in technological epochs, but also with the overall behavior of major economic indicators, e.g. labor efficiency went up and was accompanied by

increasing wage rates, technological progress, labor productivity, and capital intensity under ideal elasticity of substitution between factor inputs. In short, Taiwan's economy in this ten-year period has been biased toward labor-saving and capital-using.

4. We found out that FDI made contributions toward total output through capital formation, though not directly toward productivity. FDI brought in money capital and human capital and caused the abundant factor endowment, labor, in Taiwan to be fully exploited. It produced a demonstration effect and increased capital intensity. Definitely, it helped output expansion and economic growth.

5. In correlation analysis, productivity was found to be related to output, capital, capital intensity, wage rate and technological progress. Foreign investment was correlated with capital formation, GNP, per capital income and manufacturing production. By checking the above relationships, we found a chain of relationships among the economic variables with productivity a function of capital intensity which in turn is a function of capital formation contributed by foreign investment. Of course, for this chain effect to function well, certain conditions must hold, such as appropriate elasticity of substitution between factor inputs, so that the abundant factor inputs can be fully utilized. Second, capital intensity depends upon capital formation which must grow faster than labor. In another word, the growth rate of capital must be faster than that of labor. Checking all of the conditions, we found out that all were met in Taiwan.

The results have also demonstrated the "Verdoorn effect," the higher the output, the higher the productivity due to internal and

external economies to be gained with the expansion of output. This is also exemplified as the learning-by-doing hypothesis.

In the comparison of average change of major economic indicators between the two sub-periods of the ten-year period, it was discovered that the increasing growth rate of productivity was accompanied by increasing growth rate of capital intensity, technological progress, and elasticity of substitution between factor inputs.

This confirms that economic growth is a function of productivity which is technology determined, and technology, in turn, is a function of capital intensity which is enhanced by foreign investment. It confirms also that the behavior of the economy is interrelated in a dynamic fashion. They are not isolated elements in the environment. When making economic policy or setting up economic guidelines, we must trace them through this line of analysis or by understanding their delicate interrelations. The findings of this research, therefore, have contributed toward the understanding of the delicate and complicated phenomenon economic growth with technological progress and its transfer from ACs to DCs through foreign direct investment in the manufacturing sector.

The research findings, the theoretical framework and the interface model constitute a working tool kit for the theorists and practitioners including officials in the government, regional organizations and United Nations to cope with their problems in ITT and economic development. In this way, the problems facing the DCs in ITT and economic development can be solved and the world tension between ACs and DCs can be reduced. Judging by this standard, this study has made contributions toward human civilization.

Though this research has achieved its main objective, several areas remain to be explored, e.g., what is the exact role played by

foreign direct investment in the disaggregate level in manufacturing? What is the reaction pattern to the host government policies by the foreign direct investment in manufacturing? What is the best process or mechanism to follow in technological transfer from ACs to DCs, and some others to make the concept and mechanisms of technological transfer from ACs to DCs a more complete one.

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BIOGRAPHICAL SKETCH

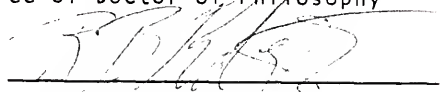
I was born in the midst of China tragedy in a remote area, in the southern part of China. When I was young, my family was financially in a very difficult situation. My parents took pains to raise a family of ten. I have been a peddler, a private in the Army, and have fought my way through higher education.

After graduation from the Military Academy and Officers' Language School, I was an Army Officer, Commander, and Diplomat. In 1969, I was awarded the BBA degree from Tamkang College of Arts and Sciences and was employed as Industrial Relations Administrator by the Chinese Petroleum Corporation.

In 1970, under the recommendation of the U. S. Embassy, I came to the United States and attended the University of Florida. Two years later, I earned a MBA and was employed as Assistant Director of Purchasing, New England Oyster House, Florida.

In 1976, as a Ph.D. Candidate, I was employed as an Assistant Professor by Howard Payne University, Texas. The next year I earned a Ph.D. degree in business administration and was employed by Eastern Illinois University as an Assistant Professor.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy



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Assoc. Professor of Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

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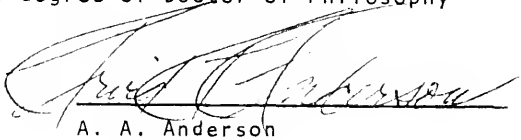

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